# HAND-BOOK

OF

# PROFESSIONAL INSTRUCTIONS

FOR THE

# TOPOGRAPHICAL BRANCH

## Survey of India Department.

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PREPARED BY

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CHART ILLUSTRATING TRIANGULATION OF THE AFGHAN BOUNDARY COMMISSION.

# PREFACE.

This Hand-book of the Topographical Branch of the Survey of India is little more than an abstract of the existing orders that have been issued from time to time, for the guidance of officers employed in that Branch, arranged in a convenient form for ready reference. A surveyor's life in India naturally divides itself into two quite distinct periods, *viz.*, The Field Season, and The Recess Season, and it has been considered a convenient arrangement to devote a chapter, sub-divided into sections treating on various details, to each of these periods. Chapter III deals with miscellaneous matters which seem to be more or less dissociated from strictly professional work, and Chapter IV is devoted to geographical reconnaissance. In compiling the first three Chapters I have drawn largely upon the former "Hand-book of the Topographical Survey Department" by Captain R. V. Riddell, R.E., 1878, and the "Manual of Surveying for India", as well as Colonel Waugh's "Instructions for Topographical Surveying", Captain Robinson's "Memorandum on the use of the Plane-table", and other minor sources. Colonel Wilmer has also afforded me the benefit of his experience. Captain Riddell's Hand-book has been used as an authoritative guide in this Branch for the past twelve years, but in the present day owing to the accumulation of new orders relating to the subjects contained therein, it has been considered necessary to compile a new Hand-book embodying most of the Circular and Departmental orders up to date.

Chapter IV is due to the pen of Major Gore, R.E., and is principally abstracted from lectures delivered at the Royal Engineer Institute, Chatham, by Major The Hon'ble M. G. Talbot, R.E., late Deputy Superintendent of the Survey of India, and published in the Professional Papers of the Corps of Royal Engineers, in Vol. XIV, 1888.

The lectures were based on the combined experience of Majors Gore, and Talbot, during several years' work beyond the North-West Frontier of India, and consequently refer more particularly to a treeless country of alternate mountain and plain, very favourable to the surveyor.

The general principles that underlie reconnaissance work are however the same, whatever the nature of the country, and much of Major Talbot's experience is equally applicable to our forest-clad Eastern Frontier. Mr. Ogle, who has had great experience in surveying in jungle-clad country, has kindly furnished some notes on the various shifts and expedients to which a surveyor has to resort in work of this class, which are also incorporated in Chapter IV.

DEHRA DUN:
*January, 1891.*

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# HAND-BOOK OF THE TOPOGRAPHICAL BRANCH.

## CHAPTER I.

## Duties in the Field.

### Section I.—Introductory Remarks.

Preliminary remarks.

1. A Topographical Survey has for its object, the delineation of the natural features of a country, and the works of man thereon, in order to produce a complete map showing all details that the scale selected will admit of.

Scales.

2. The procedure depends largely upon the scale adopted for the survey, the most usual are 1-inch = 1 mile and 1-inch = 2 miles; the instructions in this Handbook apply especially to these, but the surveyor will find little difficulty in modifying them to suit special scales when occasion arises.

Necessity of collecting information.

3. On receiving orders to undertake the Topographical Survey of any particular tract, the first business of the officer deputed to the work should be to ascertain what data can be obtained from the Trigonometrical Branch on which his survey may be based, and to supply himself with all information in the form of books, maps, or gazetteers relating to that particular district, to which he can gain access. He should also place himself in communication with the officials of the district, and ascertain the best form of carriage to employ, the means of getting supplies, the resources of the country, the availability of local labour, the general character of the physical features of the tract, its healthiness &c., as his arrangements will depend in no small degree upon such details.

Constitution of a Topographical Party.

4. The general constitution of a Topographical Party (subject however to considerable variations) may be taken at 1 Deputy Superintendent in charge, 4 European Surveyors and Assistant Surveyors,

10 Sub-Surveyors, 140 Khalásís, 16 Chaprásís, and a police or barkandáz guard according to the exigencies of the case. A guard is chiefly useful in getting the pay of the establishment from the nearest treasury, and in distributing it to the various detached parties.

Carriage.

5. In selecting carriage the officer in charge should remember that it is most important to adopt the particular kind of carriage in use in the country under survey. *Cæteris paribus*, camel carriage is the best where long marches over bad ground have to be encountered; but it has the disadvantage of requiring far more packing and unpacking than cart carriage, as the loads must be removed from the camels at the close of a march, whereas this is unnecessary in the case of carts, except for such articles as are required for daily use: moreover disabled carts are more easily replaced than sick camels. Delicate instruments should always be carried by men; a certain number of the 140 khalásís on the establishment should be especially selected from the *kahár* caste for this purpose. If it ever becomes unavoidable to convey instruments by cart, a layer of boughs from ½ to 2 inches in diameter placed under the boxes will be found to be an excellent substitute for springs.

Division of the field work.

6. The prosecution of a Topographical Survey in the field may conveniently be divided into four branches, *viz.*, Triangulation (including previous reconnaissance), Plane-tabling, Traversing and Checking. The first and last are considered to be especially the duty of the Deputy Superintendent, besides the general control of the operations.

## SECTION II.—TRIANGULATION.

Survey to be based on triangulation.

1. The only safe basis for topographical operations is beyond all question a system of accurate triangulation, whereby undue accumulation of error is precluded in the extension of the work, and at the same time limits are set to the intrusion of error in the internal details. For all topographical purposes the work of the Trigonometrical Branch, executed as it is with every possible refinement, must be considered errorless. There are few parts of India into which it has not penetrated, and wherever its stations are found the four initial elements required for commencing a survey are available, *viz.*, (1) the latitude and

longitude of a fixed point; (2) a base of ascertained length; (3) an initial azimuth or true direction of the meridian; and (4) the height of some given point above sea level.

Previous reconnaissance.

2. Before commencing the actual observation of the angles of the triangles, a previous reconnaissance with the plane-table is desirable, by which the most advantageous positions for the stations are chosen, and points selected for the erection of temporary signals, such as poles, flags, &c. In skilled hands this rough reconnaissance may become a very fair approximate map of the country, and will well repay a large amount of care and thought bestowed upon it. The identification of the so-called "intersected points," when observed from three or more stations, depends largely on the clearness and accuracy of this preliminary work, moreover the selection of "well conditioned" triangles is much facilitated by it, and it is of use in many less obvious ways which a surveyor soon learns to appreciate. The actual method of using the plane-table is here assumed to be well known to the surveyor: a description of it will however be found in the next Section. This field chart of triangulation should be of such a scale, that all the points intended to be fixed by triangulation can be clearly entered and named, or numbered, upon it. A scale $\frac{1}{4}$ of that of the detail survey will generally be found suitable. All the rays that have been observed should be drawn on the chart, and inked or coloured up to date at least once a week. At the close of the field season, this chart should be in such a state, that any officer conversant with such proceedings would be able to lay out from it the computations connected with it without any preliminary trial.

Number of fixed points required.

3. The size of the triangles and the number of fixed points per square mile must depend on the scale of survey. All consideration of scale may, however, be got over by regulating the number of points to be given on *a certain area of the paper* on which the final survey is made, instead of on a certain area of ground. A good estimate is one fixed point on the average to each six square inches of paper.

Various classes of triangles.

4. For the one inch scale the Great Trigonometrical triangles should be first broken down into triangles of about 8 to 12 miles to the side, and subsequently into still smaller ones, if a sufficient number of

D. O. No 346, dated 2nd February 1875.

"intersected points" cannot be otherwise obtained. The names by which the various classes of triangles are distinguished have varied at different times in the several Topographical parties: the following is recommended for adoption. The term "principal" to be retained for Great Trigonometrical work only; the next class, *viz.*, those triangles into which the principal ones are first broken up, and which form the main skeleton of the triangulation to be called "1st class secondary": the next in importance are to be known as "minor," and those employed for fixing "intersected points" to be called "tertiary." The term "intersected points" applies to those which are not visited by the triangulator, but fixed by intersection from two or more stations. The majority of points fixed for the use of the plane-tabler are of this kind, and for the most part consist of conspicuous rocks, or hill tops, poles or flags in trees, single trees, buildings &c. All ground not included in the principal G. T. triangulation must be covered with a network of 1st class triangulation, based on the sides of the G. T. triangles and executed, like all other operations of extension, with particular care. If no Great Trigonometrical triangulation exists in the district under survey, it will be necessary to measure a base-line and institute astronomical observations; but such work being beyond the scope of a Topographical Survey, as the term is ordinarily understood in India, is not entered upon in this Hand-book.

Rules for extending triangulation.

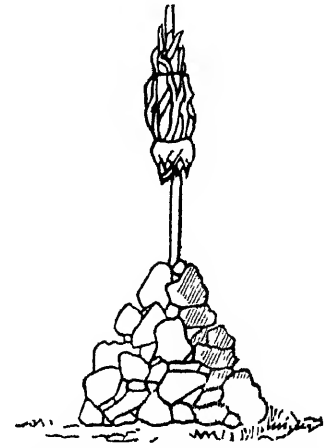
5. Extension of triangulation may be carried on by minor series, instead of a network of 1st class secondary triangles. In a hilly country the latter would probably be the more convenient: a large river with high banks would incline the balance in favour of the former. If a minor series be used, every endeavour should be made so to arrange it, that it emanates from, and closes upon, a side of the G. T. triangulation. Further hints on this subject may be found in Colonel Waugh's "Instructions for Topographical Surveying", printed as an Appendix to the "Manual of Surveying for India" a work which, though obsolete in some particulars, contains much valuable information, and should be in the hands of every surveyor in India.

D. O. No. 64, dated 25th May 1866.

Description of signals to be employed.

6. Signals are of two kinds, luminous and opaque. The former consist of heliotropes for use by day, and lamps for nightwork: lamps are very rarely used in topographical work, whereas heliotropes are in constant employment, to the almost entire exclusion of opaque

signals for marking stations of observation, and the observer is recommended to provide himself with an ample supply, say 20; the smaller size 6 inches in diameter being in the majority. Opaque signals are generally used only to mark the site of intersected points. A very useful one is that known as the pole and brush, of which a diagram is here given. This may be either fixed up by a pile of stones 5 or 6 feet in height heaped against it, or by tying on the top of a conspicuous tree. Another very good form of signal for fixing on a conspicuous tree is made of thin lathes of bamboo worked into the shape of a deep basket. Two of these are joined together mouth to mouth and fastened on to a bamboo running lengthwise through them. This signal when new is very clearly visible at long distances, and being very light is comparatively easily attached to the topmost branches of a tree. There is no better signal than a single tree left standing on a hill top from which all contiguous jungle has been removed; and it is often found very convenient to leave a tree standing thus in the vicinity of a station, taking care that its position does not cause it to throw a shadow over the heliotrope placed on the station mark. It is desirable that its distance and direction from the station itself, should be recorded in the angle book. Bell tents may under certain circumstances form good signals, especially when looking down from a hill upon a plain below; but they are not often employed. Flags are not much recommended, partly because they are very liable to be stolen, and partly because unless the staff itself is seen they do not sufficiently define the situation of the point to be observed.



Heliotropes described

7. A heliotrope (called also heliostat and heliograph) consists of a plane circular mirror, so mounted on a small tripod as to be movable on two axes, one vertical and the other horizontal, whose directions pass accurately through the centre of the mirror, at which point a small hole about $\frac{1}{10}$ of an inch in diameter, is drilled through the glass. Each heliotrope is accompanied by a small sight-vane, consisting either of an aperture in a board with two cross wires spanning it; or of a leaden weight (or even a lump

of clay) of 2 or 3 lbs, into which is inserted vertically a straw or very thin slip of wood, on which a ring of thread is tied loosely, so as to be movable up and down at pleasure.

Method of aligning heliotropes.

8. The process of aligning a heliotrope, or so placing it that the sun's rays are reflected in any desired direction, is very simple, and soon learned by ordinary khalásís. It is carried out as follows:—The sight-vane is carefully centered over the station mark, and the heliotrope then placed at a convenient distance from it (about two feet is suitable) and facing the point on which it is to be aligned, in such a manner that the khalási can see both the sight-vane and the distant mark, through the hole at the centre of the heliotrope. By moving the heliotrope slightly, the distant mark, the cross wires of the sight-vane, and the hole, are then placed in the same straight line. The mirror should now be turned towards the sun by means of its motion on the two axes (the tripod remaining fixed) in such a direction that the image of the hole, which is a small black speck in the middle of the bright reflection of the mirror, falls on the cross wires of the sight-vane. An observer at the distant mark will then see the sun reflected in the mirror. Some observers prefer centering the heliotrope itself, instead of the sight-vane, over the station mark. There is no choice for the one method, rather than the other.

Theodolites.

9. The best instrument for 1st class secondary triangulation is undoubtedly the 12-inch or 14-inch vernier theodolite, but, where inferior precision is aimed at, the 8-inch or even 6-inch will suffice. These are very handy and portable instruments, with simple adjustments, and in the hands of skilled observers capable of giving results more than good enough for any topographical work. The average triangular error for a season's work should certainly not exceed $2\frac{1}{2}''$ or $3''$, if luminous signals are used. The adjustments have been so well and so often described in other works that it is needless to repeat them here; the reader may refer to a "Memorandum on the Vernier class of Theodolites" by Mr. J. B. N. Hennessey, F.R.S., printed as an Appendix to the "Manual of Surveying for India."

Construction of stations.

10. It is indispensable, in order to get the best results from these theodolites, that they should be placed on a perfectly stable foundation; in most cases a certain amount of building is necessary to ensure this. The ordinary

procedure is to build with bricks (or stone) set in mortar, a central pillar two or three feet in height according to requirements, and just large enough to accommodate the theodolite stand, say two feet in diameter. In the centre of this on its upper surface a heavy stone is let in, on which is engraved a circle about three inches in diameter, with a central dot to mark the exact site of the station. Around this pillar, but not touching it, is built a rough masonry platform of stones and mud, on which the observer stands when at work: the space between the pillar and platform, which may be about two inches wide, is filled in with loose grass or sand. This is the usual construction where building is necessary: many stations, however, are placed on solid rock, or on roofs of houses, in which case it is sufficient to engrave the circle and dot *in situ*. On black cotton soil, or in other circumstances where the ground is very unsteady a fairly good temporary support for the theodolite may be made by driving deep into the soil three large tent pegs or stakes on which the legs of the stand may rest. The stations are generally built by a tindel during the time that the reconnaissance is in progress, so as to be ready for use when the angular measurements begin, and at the same time khalásís are sent out with instructions to fix up signals on various conspicuous points pointed out by the triangulator.

Special conditions of work during first season.

11. As plane-tabling and traversing both depend on the triangulation, which has to be previously computed, it will generally happen that the whole strength of the party will, for the first year, be employed on reconnaissance and triangulation only; in this case careful arrangements must be made that the work of each observer joins properly on to that of his neighbour, and that the same stations on the common flank are used by both.

Satellite stations.

12. It may occasionally happen that the observer has through inadvertence intersected, when observing, not the exact station itself, but a point quite close to it: on the other hand it is occasionally necessary, in order to avoid intervening obstacles, to place the theodolite a short distance from the mark for some particular ray. In such cases all that the observer has to do in the field, is to enter carefully in his angle book the circumstances of the case, giving the distance of the "satellite station" as it is commonly called, and its direction referred to one or other of the distant stations. The computation of the correction to be introduced

is then a very simple matter of plane trigonometry, and is generally postponed till the calculations are taken in hand during the recess. Further details connected with satellite stations will be found in Chapter II, Section I.

Centering of signals and theodolites.

13. The observer will of course take the greatest care in centering his theodolite exactly over the station mark, but he should remember that all his care will be thrown away unless he can succeed in impressing on his signallers the necessity for equal care in centering the heliotropes, &c., and he will do well to make a show of extreme scrupulousness on this point whenever setting up his instrument, even where accuracy is not imperative, in order to cultivate this habit among his subordinates. It is advisable to send two men out in charge of each heliotrope, partly because the khalási, whose duty it is to show the signal nearly all day, requires assistance in cooking &c., and partly because the second man who is generally untrained has thus a good opportunity of becoming practically acquainted with heliotrope work, with the least possible expenditure of extra trouble in teaching: in case of sickness also the presence of a second khalási is imperative.

Management of heliotrope signals

14. The routine of heliotroping is necessarily made simple in order to be within the comprehension of the uneducated men who are employed on it, and consists of a few readily understood signals as follows:—When the observer wishes to observe a distant station heliotrope, he, with his own heliotrope (which may be 12 inches in diameter with advantage) flashes continuously on that point, until the signaller has adjusted his heliotrope and shows a steady light; he then ceases flashing, and the signaller is required to keep his light fixed through the whole day. If he gets careless a few flashes are again sent to him, by which he understands that he is to see carefully to the adjustment of his heliotrope, as it has probably got off the line. When the observations to any station are completed the heliotroper may be dismissed, or "given his jawáb" as it is commonly called, as follows:—The observer having in the regular way obtained a good steady light from the heliotroper, fixes his own heliotrope steadily upon him (*i.e.*, not flashing). The heliotroper seeing this suddenly extinguishes his light, the observer immediately follows suit; the heliotroper again shows a steady light, the observer does the same; the heliotroper extinguishes his, the observer does likewise; and this process is repeated three times till the heliotroper

is satisfied of the observer's intention; he then gives a few flickers with his heliotrope, to signify that he understands the signal, dismantles his heliotrope, sets up a pole and brush with stones or earth piled round it over the station mark, (*vide* diagram page 5) and proceeds either to the observer's camp, or to the next station allotted to him, according to orders previously received. There is another method of giving the "jawáb," *viz.*, to display two heliotropes thirty or forty yards apart, in answer to which the heliotroper extinguishes his light three successive times as before. In some Topographical parties it is customary to give a partial "jawáb", consisting of one reciprocal extinction, by which the heliotroper is to understand that his work for *that day only* is over; but this is liable to be mistaken, and cannot be recommended except with experienced and well-trained heliotropers.

Reduction of excess of light.

15. At short distances even a 6-inch heliotrope will be too bright to observe with precision, and its light must be partly reduced; this may be done by a diaphragm limiting its aperture to 2 or 2½ inches; but a more convenient method is to have a piece of muslin, stretched on a little slip of bamboo bent round into the shape of a tennis bat, held by a khalási in front of the object-glass of the telescope. A cardboard cap, with muslin stretched over the aperture, will answer the same purpose.

Difficulty experienced with low sun.

16. When the sun is near the horizon, its rays may fall so obliquely, on either the observer's, or the heliotroper's mirror, that it is seen with difficulty: this may in skilful hands be remedied by double reflection. The method, however, requires a second heliotrope, and besides being a little too complicated for the ordinary native, is of doubtful advantage, as a large quantity of light is lost by the double reflection.

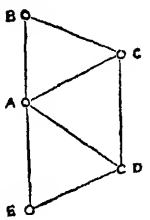
Measurement of horizontal angles.

17. The class of theodolites used on the Topographical surveys are generally provided with three verniers, and with such, two zeros and a change of face on each zero, will give sufficiently good results: where for any reason particular accuracy is aimed at, as in large triangles of extension, the number of zeros may be doubled with advantage. In the first case the zeros and changes will be F.R. 0°, F.L. 180°, F.R. 30°, and F.L. 210°, and in the second, F R. 0°, F.L. 180°, F.R. 15°, F.L. 195°, F.R. 30°, F.L. 210°, F.R. 45°, and F. L. 225°. Intersected points are observed on one zero only, and one change of face: for them, however, the change of face is

hardly necessary on the score of precision, but the second reading serves as a check on large errors, which would otherwise have to be guarded against by setting the instrument successively to the recorded readings, and then noting if the objects were duly intersected. There is little choice between the two methods.

18 The angles at a station are taken thus: supposing the observer to be at *A*, and the signals at *B*, *C*, *D*, *E* all visible, the instrument is carefully levelled and adjusted, and so fixed that some station, *B* for instance, reads 0°, or zero in microscope *A*; *B* is then called the zero-station. Suppose the telescope to be brought up from the left hand of *B*, and turned gently, so that *B* may enter the field of view, and come near the centre wire, but not pass over it; the instrument must then be clamped, and the bisection of *B* completed by using the slow-motion screw. All the micrometers, or verniers, are now read, and the assistant records the readings in a fair legible hand in the angle book. The observer should then look again into the telescope to see that *B* remains bisected. If found correct the telescope is to be gently unclamped and moved towards *C*, care being taken not to overshoot it. The clamping, bisecting, and reading is done as before, and similarly also for *D* and *E*. A complete set of observations is thus obtained at zero 0° by a continuous motion from left to right. Now, after overshooting the station *E* the telescope is brought back by a continuous motion from right to left, to each station in succession, and the readings recorded. This will give a second set at zero 0°. When the signals to be observed lie all round the station observed at, as at the centre of a polygon, the observer must be careful to complete each swing by intersecting the same signal as he commenced with. Thus if he begins with *B* in going round from left to right he will end with *B*, and again beginning with *B*, having first overshot it, he will swing round from right to left, and end on *B*. Unless this is done the last angle in the swing can only be deduced by subtracting the sum of all the others from 360°, and it is not therefore a *measured* angle at all.

*Continued.*




19. Now turn the telescope through 180° in a vertical plane, and round 180° in azimuth, so that if the face of the vertical circle were previously to the right hand, it will now be to the left hand; *B* will then read 180°, and this

*Continued.*

is called zero 180° F.L., the former position being zero 0° F.R., *i.e.*, face right. Proceed as before, and take two sets of observations, the motion of the instrument being in one set continuous from left to right, in the next from right to left.

In observing intersected points it is necessary that at least one (but preferably more than one) station should be observed with them in the same round, and it is better to commence and finish with a station as a check on any movement of the instrument during the round. In 1st class secondary triangles all the three angles should, if possible, be measured. It is a good plan to number the rays to intersected points, retaining the same number for each point throughout the record: moreover intersected points should have a short description attached to them in the column of remarks, to assist in subsequent identification, and to ensure the same part of the object being observed in all cases.

Measurement of vertical angles.

20. Vertical angles to all stations should be measured at about the time of minimum refraction, *i.e.*, between 2-30 P.M. and 3-45 P.M., and always with at least one change of face: for intersected points the time is of less consequence, and so long as the observations are not made in the early morning or late evening hours, the observer may use his own discretion about infringing the rule. If vertical angles are observed at an hour very different from that of minimum refraction, it is desirable to observe some station at the same time: the reason for this is, that the height of the station being known, the observer is enabled to compute the refraction at the time of observation, by means of the vertical angle then taken to it. For stations the observations should be reciprocal, because refraction is not only thereby eliminated, but because they furnish the coefficient of refraction to be employed in reducing single, *i.e.*, non-reciprocal, vertical measurements. The heights of the instrument and signal above the station platform must always be recorded in the angle book; and in observing vertical angles to intersected points, the particular part of the object intersected should be noted, as well as its height above the ground level.

Description of stations.

21. The stations of observation must be very carefully described, so that any one subsequently wishing to make use of them may have no difficulty in finding or identifying them. The directions and distances of the neighbouring villages should be given, and the local name of the spot, if any exists: C M. No. 156, dated 16th October 1884.

also the best means of getting to the station, and the name of the village in whose lands it is situated, together with the name of the district, and any other information likely to prove useful in the future. This description must be written in the angle book at the end of the observations appertaining to that station, in a clear legible hand, especial care being taken to write proper names in a good round style, or even to print them.

Preservation of stations.

22. The elaborate precautions taken for the preservation of the principal stations of the Great Trigonometrical Survey are superfluous in the case of topographical work, and it will suffice if a pile of stones or earth is heaped over the site of the station. The topographical surveyor must, however, when making use of the principal G. T. Stations, be careful to leave them properly protected according to the rules laid down in the Order marginally noted, and must moreover report to the Deputy Surveyor General if they cannot be identified, or have fallen into a state of disrepair.

D. O. No. 50, dated 15th February 1866.

Observatory requirements.

23. It is indispensable for good observing that proper shelter from wind, sun, or rain should be provided for the theodolite, and the officer in charge of the party is responsible that a suitable observatory tent accompanies each triangulating party. Each observer also requires a recorder, whose business it is to enter the results of the observations in the angle book as they are made, and to call the observer's attention whenever there appears to be any discrepancy in the work. His business also is to take out the means of the three verniers while the work proceeds, and if possible the angles also, so that any obvious error may be remedied on the spot. With careful management and judicious marching one station a day can be observed at in favourable weather when the heliotropes show well.

Angle books.

24. It is most essential, in order to avoid errors and loss of time, that the angle books in which the measurements made by the theodolite are recorded, should be systematically and clearly kept up. All entries must be made in ink on the spot, and no erasures are permitted. In the form of angle books P. 40 recently introduced into the Department, and which must be in future adhered to, at each opening the left hand page serves for the recording of horizontal and the right hand for vertical angles. The first

column should contain the name and description of the station or intersected point, and should be as concise and graphic as possible; each ray, moreover, should have a distinguishing number. In the second column the position of the theodolite—face right or face left—as the case may be, should be entered, the upper line being reserved for the former, or F. R., and the lower for the latter, or F. L. In the columns A, B, C, are entered the readings of the three verniers, (the degrees and minutes are recorded in the first only). Columns 6 and 7 speak for themselves. Duplicate angle books are not required.

25. These being duly filled up and examined, a so-called "Abstract of Horizontal Angles" is entered in column 8. These figures show what the true readings of the various stations and points would be if the zero-station read 0°-0′-0″, and are arrived at by merely subtracting from the figures in column 7 (increased by 360° if necessary) successively the true reading of the zero-station in the same column. In columns 6 and 7 the readings of first-class angles should be recorded to the nearest hundredth of a second, of secondary angles to the nearest tenth, and of tertiary angles to the nearest second.

Abstract of Horizontal Angles.

D. O. No 346, dated 2nd February 1875.

26. In filling up the right hand page devoted to vertical angles, the only point calling for notice is the level correction. The rules for applying this are as follows:—The reading of each end of the level is to be registered in two columns marked "object-end" and "eye-end." The object-end readings are to be marked + and the eye-end readings marked —. The algebraical sum of the whole is to be divided by the number of level readings, each end being considered an independent observation. The quotient will be the level error in terms of the level-scale, which, multiplied by the angular value of one division of the scale, will give the angular correction with its proper sign, additive algebraically to altitudes, and subtractive from depressions.

Level corrections.

27. There are several methods by which the value of the divisions of the level-scale can be ascertained. The best is by means of a "bubble-tester", an instrument of very simple construction. It consists essentially of a bar or framework on to which the level is firmly fixed by contrivances for the purpose, and admitting of being raised or

1st method of ascertaining value of level-scale.

depressed at one end by a screw of known pitch. A graduated disc is attached to the head of the screw on which is read off the change of elevation of the bar caused by turning the screw; and hence by a comparison of this change with the divisions that the bubble passes over, a value of each division is arrived at. An instrument of this kind is generally only available at the Calcutta or Dehra offices.

2nd method.

28. The value may also be ascertained by affixing the level to the frame of the vertical circle (or making it ride parallel to the telescope), and then taking readings of the verniers on the vertical arc in two positions of the bubble, whence by comparing the number of the divisions of the level-scale run over by the bubble, with the corresponding angular motion of the vertical circle as read by the verniers, the value of one division is arrived at by simple proportion. At least fifty separate observations should be made; they should not all be taken at the same time, but under as great a range of temperature and circumstances as possible, and with various lengths of run, and at different parts of the vertical circle, taking special care to avoid allowing the bubble to approach too near the end of the scale on the one hand, and on the other avoiding small runs.

3rd method.

29. There is yet another mode of determining the value of a level scale, applicable to levels of azimuthal instruments, which does not necessitate the detaching of the level. It is performed as follows:—Bring the object or eye-end of the telescope plumb over a footscrew. Turn the whole instrument till the telescope is directed to a distant mark at the time of day when the altitude is steady. Now level the instrument. It is clear that if the screw under the telescope end be raised or depressed, the amount of dislevelment so occasioned may be measured both by the verniers of the vertical circle and by the level, whence a comparison of the two measures gives at once the value sought. This method should be only employed at or near the time of minimum refraction, *i.e.*, within half an hour or so of 3 P.M. either before or after.

Method of fixing a level to vertical circle.

30. In applying a level to a vertical circle for the purpose of measuring the value of its scale, the best plan is to fix on the bars, or on the telescope, two Vs of wax, in which the level can be made to sit firm, taking care to secure it from accident by tying it on. The level should

be carefully cross-levelled, so that it may occupy the same position under trial, as when in actual use. If there be no cross-level attached, one may be fixed on temporarily with wax, before dismantling the level; but if means are not available for this purpose, then, before taking the level off for trial, mark with pen and ink on the glass the outline of the bubble. This approximate cross-levelling, however rough, is far better than trusting to chance.

Caution in using levels.

31. Levels being very sensitive thermometers, care must be taken not to influence them by breathing on them, or by too near an approach of the body.

Abbreviations.

32. The following abbreviations are recommended for adoption in the angle books and computations:—

| | | |
|---|---|---|
| H.S. | for | hill station of the Great Trigonometrical Survey. |
| T.S. | „ | tower „ „ „ „ |
| h.s. | „ | hill station of secondary, and minor, triangulation. |
| v.s. | „ | village „ „ „ „ |
| t.p. | „ | tree pole. |
| v.t.p. | „ | „ near village. |
| h.t.p. | „ | hill tree pole. |
| t.f. | „ | tree flag. |
| temp. | „ | temple. |
| Hel. | „ | heliotrope. |

## SECTION III.—PLANE-TABLING.

General remarks on the plane-table.

1. The detailed delineation of ground by the Topographical Survey parties in India is effected almost exclusively by the use of the plane-table, an instrument which for this purpose far excels all others in convenience, accuracy, and rapidity, and one with which every surveyor should be thoroughly acquainted It works to the greatest advantage in open and hilly country, and to the least in flat jungly tracts: in the latter case, and in others where much boundary work has to be done, it may be advantageously supplemented by traversing with theodolite and chain This latter, however, is a branch of surveying belonging more properly to the Revenue Branch, in which it is largely resorted to,

and it will therefore be needless to explain it further here, as a detailed description of it may be found in the Manual of Surveying for India page 222.

Description of plane-table and stand.

2. The instrument and its appurtenances are of the simplest possible description. The table itself is merely a plain ordinary drawing board 30 inches × 24 inches, and one inch thick, solidly made of teak, planed perfectly true on its surface, and provided with the usual arrangement of screws in slotted holes at the back to prevent warping. In the centre of the posterior surface, a brass plate tapped to receive a brass clamping screw is firmly attached. The stand is a folding tripod, of a height to suit the observer; the top, to which the three folding legs are attached by a contrivance exactly similar to that in use with small theodolites, consists of a triangular block of solid wood about 6 or 7 inches to the side and 1½ inches thick. A hole is drilled through the middle of this block through which the clamping screw passes loosely; the screw being inserted into the plate under the plane-table, and turned home, serves to clamp it to the block in any desired position.

Description of plane-table ruler.

3. The ruler is usually about 30 inches long, 1½ inches broad, and ⅛ of an inch thick. At one end of it stands the object-sight, and at the other the eye-sight; these may be either permanently fixed in position, or made to fold down flat on the ruler by a flap arrangement, according to the taste of the surveyor. The slit of the object-sight, down the middle of which a fine thread or horse-hair is fixed, should not be less than half an inch in width, and 5 inches in height. In the eye-sight three or four small holes should be drilled at intervals in the fine cut which forms the sight. The ends of the ruler should be capped with thin sheet copper, to save the ruler from splitting. When the elevation or depression of an object to be intersected is more than can be embraced by the five inches of the sights, the intersection must be effected with the assistance of a plummet suspended in the exact ray, either before the object-sight, or behind the eye-sight, as may be required. The same result may be attained by stretching a thread tightly from the object-slit to the eye-slit on the top of the brass supports, and so contrived that it shall lie in the plane passing through the two slits. The eye-slit and the thread of the object-sight must be in a plane perpendicular to the plane of the ruler. The edge of

the ruler should be parallel to the junction of the plane of the ruler and that of the eye-slit and thread of the object-sight. This latter condition is not absolutely necessary except for "setting by the back ray."

Mounting a plane-table.

4. To "mount" a plane-table a sheet of good drawing paper must be thoroughly wetted, care being taken that if wetted by using a sponge, the surface should not be injured by too heavy rubbing. The sheet when thoroughly expanded, should be rolled up and laid aside till wanted, not being allowed to dry meanwhile. A piece of fine longcloth, large enough to overlap the board two or three inches all round, is next to be thoroughly washed free from dirt and starch, and while wet laid flat on the board previously damped with a sponge. Very thin paste is then laid on the cloth and rubbed in, and the overlap secured under the board with strong paste or glue. The paper still damp is now to be laid flat on the cloth, and pressed down (not rubbed) working from the centre outwards; and the edges are to be secured with strong paste to the under surface of the board. The paper when thus mounted should not be allowed to dry too quickly.

Other articles needed for plane-table equipment.

5. In the following instructions for plane-tabling it is assumed that the reader has passed through the essential parts of the course laid down in the order marginally noted, and is so far conversant with the theory of the instrument as to be fit for actual work in the field. In addition to the plane-table and ruler, the surveyor will require an 8-inch rectangular magnetic compass, a clinometer to be hereafter explained, a large strongly built umbrella with a handle sufficiently long to stand on the ground, a village book, pencils, rubber, knife and small spring-dividers.

D. O No. 4, dated 4th March 1835.

Projecting a plane-table.

6. Plane-table sections, or field sheets, on the scale of 1-inch to the mile, should occupy 15′ of latitude from north to south, and 15′ of longitude from east to west, and should be set out to conform to degrees and quarter-degrees. The sections should be sub-divided into squares of 5′ × 5′, and the trigonometrical stations and points projected thereon by co-ordinates, and tested by distances. Printed scales of latitude and longitude, suitable for all parts of India, can be obtained from the Head-Quarter's office on application.

Projecting a plane-table.

7. The table itself is considerably larger than the plot of the section to be surveyed; this is necessary to enable the surveyor to project a certain number of trigonometrical points outside his work, thereby ensuring greater accuracy of fixing towards the edges of the section; and the section should be so placed on the board as to include the most useful of these. The best way of doing this is to cut out a sheet of paper (or preferably a piece of tin) of the exact size that the plane-table would be when reduced to the same scale as the chart of triangulation, generally $\frac{1}{4}$-inch = 1 mile. This piece of paper or tin is laid on the chart, and shifted about over the allotted section so as to embrace the best outside points,* and is then outlined on the chart in pencil. Measurements from the corners of this outline to the points where the lower parallel of latitude of the section cuts the edge of the board, will now enable the surveyor to place this line in its proper position. In a similar manner he can obtain the proper place for one of the lower corners of the graticule, which he will then proceed to project by help of the appropriate Table (XXXI to XLI) in the 3rd Edition of the Auxiliary Tables. The lower parallel must be first laid off, then the distances on the meridian from either extremity; these latter lines are then intersected by diagonals from the extremities, fixing the two north corners of the graticule. If the distance between them is now found correct by the table, the whole graticule may be assumed to be right, and the sub-division into 5′ squares and the plotting of points may then be proceeded with. A good deal of trouble in projecting plane-tables may be saved by the use of thin metal plates called "graticule plates." In these are punched minute holes corresponding to the positions of the corners of a 15′ graticule for the latitude of the different parts of India. The corners are pricked through the appropriate holes, and the graticule is completed as above. These "graticule plates" are, however, more generally employed for projecting rectangular, than spherical, graticules, as the latter vary according to the latitude, and a separate set of holes is required for every parallel. Points, of which the spherical co-ordinates have not been computed, must be laid down by distances—no point which cannot be laid down by at least three distances can be considered as certainly free from error. In placing the section on the board as described above it is not at all

* It is often extremely convenient to have one well-defined, very distant point, such as a sharp hill peak, to work with.

necessary that its edges should be parallel to those of the table, but they should nowhere be so close as to leave less than 1½ inch margin.

Commencement of work on plane-table.

8. When commencing work the surveyor should set up his table on a principal (or at all events on a well-fixed) trigonometrical point, in as commanding a position as possible, placing it level and nearly over the station mark.

*Continued.*

9. He should then truly orientate his board, by placing his ruler on the point on which he is standing and on the most distant point plotted on his board, and then turning the table bodily round in azimuth until the true distant point is intersected by the sight-rule. This is commonly called "setting" the table.

*Continued.*

10. He should next test the accuracy of every trigonometrical point on his board, by bringing them in succession under the sight-rule; if any are found to be wrong, the plotting of them should be examined and corrected if necessary.

*Continued.*

11. He should now place the compass, without taking it out of its box, on some convenient part of the table out of the work, and shift the compass box till the needle reads 0° and then mark with a firm pencil line the edge of the box. This position of the box should always be used subsequently for all ground nearly in the same meridian as that of the station at which the compass was set up.

*Continued.*

12. He should next draw rays to any forward points which he considers suitable to visit for the purpose of sketching. These rays should be produced, and their extremities marked on both edges of the table. On arrival at the forward point he will place himself accurately on the ray from the last station, and will "set" his board by laying his ruler on the ray, and turning it round with the board until it intersects the last station. This is termed "setting by the back ray," and there is no better method of placing the table in true azimuth; it is quite independent of abnormal compass variations. Rays now drawn from any other near trigonometrical points, so as to intersect the setting ray, (preferably as nearly at right angles as possible) accurately determine the position of the surveyor.

13. The other method of setting up the table is by interpolation, and there are several cases constantly occurring in practice. A table may be set by compass and two trigonometrical points, or by three points without a compass, (with certain exceptions), but in neither of these cases is there any test of accuracy: in the first any abnormal magnetic variation vitiates the setting, especially if the two points are at a considerable distance; and in the second if the circle drawn through the three points passes through or near the surveyor's position, the setting becomes very ambiguous and unsatisfactory. Hence the plane-tabler should, if possible, fix himself by four points* at least, and should consider the compass as merely a convenient accessory for obtaining a first approximation, relying only upon the triangulated points for final work.

Interpolation.

14. It would be impossible within the limits of a Hand-book to enter into all the cases of interpolation that may occur; the reader is referred to a "Memorandum on the use of the Plane-Table for Topographical purposes" by the late Captain D. G. Robinson, R.E., printed as an Appendix to the "Manual of Surveying for India", in which much useful information may be found. It will be sufficient to mention here as a general rule for guidance that, the table being approximately set up by compass, the nearest points (so long at least as the rays to them form an angle not too acute) should be used to fix the observer's position by their intersection, and that then the ruler being placed on this intersection and on the most distant point on the board, the table should be rotated till the sight intersects the distant object *in situ*, and then a second approximation be made by rays from the near points again, and readjustment on the distant point. This rule may be thus formularized for easy recollection:—"Use *near* points for finding your position, and *distant* ones for adjusting your meridian": most of the cases are based on this. The case in which the points used for the setting are so situated that a circle passing through them also passes very near the observer's position, should always be avoided, but if this is impossible it will be better to trust to the compass for "setting," and fix the position by any two of the points giving a suitable angle.

*Continued.*

* No number of points will render the fixing anything but ambiguous, so long as the condition exists, that a circle can be drawn, which will approximately pass through them and the observer's position.

15. The plane-table may also be used as a traversing instrument by the process explained above of "setting by the back ray," the distances being measured by chain or perambulator. The traverse should be checked by fixing from trigonometrical points whenever an opportunity occurs, and the method should not be resorted to unless absolutely necessary, as it is not calculated to bring out the special advantages of the instrument.

Traversing with the plane-table.

16. An admirable method of measuring the distances between the plane-table fixings, especially if very far apart, and separated by inaccessible or rugged ground, is that known in the Department as the "bar-subtense method", due to Colonel Tanner. In special cases the advantages of this system are incalculable, but it should not ordinarily be resorted to in open and level country, where the distances are short; under such circumstances it cannot compete with the chain or perambulator in accuracy, and moreover requires a theodolite to be carried by the plane-tabler. The principle of it is to obtain the distance by computation, after measuring the angle subtended by a bar of known length placed at right angles to the ray whose length is required; this bar is placed generally, but not necessarily, in a horizontal position as being much the most convenient, for reasons given below.

Measurement of distances by bar-subtense method.

17. The bar is generally made 10 feet long, (or 20 feet if for great distances) which suffices for rays of 1½ miles in length, and at each end is a diamond-shaped board, about 1½ feet along one diagonal, and 1 foot along the other, facing the observer. The longer diagonals are vertical and so adjusted as to be exactly 10 feet apart. In the centre of each board is a black spot about 1 inch diameter, which is useful for short distances. The measurement of the subtended angle is effected with a 7 or 8-inch theodolite and is repeated 15 to 20 times (or for great distances even more) by means of the tangent-screws only. The screws of both upper and lower plates are first unscrewed to their full extent, and then the lower plate is clamped. The board at the left end of the bar is then intersected by moving the upper plate, then clamping and finishing the intersection with the tangent-screw. The limb is then read off and recorded, all the verniers being entered in the record. Now, by means of the upper plate tangent-screw only, intersect the board at the right end of the bar, and read off one vernier to give an

*Continued.*

approximate value of the subtended angle, which will be found useful as a check against gross errors. Now with the lower plate tangent-screw bring the telescope back to the left board, then with the upper plate screw bring it on the right board again, and repeat the process as often as necessary, keeping count of the number of repetitions, and finishing on the right board. Finally read and record all the verniers, and divide the difference of the means of the first and last readings by the number of repetitions. This gives the value of the subtended angle, and a comparison with the approximate value obtained as explained above, will guard against gross errors, or against a wrong reckoning of the number of repetitions made. If so many measures are made that the tangent-screws have not sufficient play to include them all, they must be unscrewed again, care being taken that the *lower* one is unscrewed while the *upper* plate remains clamped, and the *upper* one while the *lower* plate remains clamped.

Computation of the distance.

18. Having thus obtained the value of the subtended angle, the distance corresponding may be either taken from a table† previously prepared, or computed on the spot by a table of natural cotangents, or a special scale may be prepared from which the distance may be taken off with dividers at once. The true distance in feet $d$ is $\frac{l}{2}$ cotan. $\frac{s}{2}$, where $l$ is the length of the bar in feet and $s$ is the subtended angle; but the formula $d = l$ cotan. $s$ is quite accurate enough and more convenient. The approximate formula $d = \frac{l}{s \sin 1''}$ is also practically accurate within the limits of observation and is the most convenient of all, as $\frac{l}{\sin 1''}$ may be taken as a constant, and then division by $s$ in seconds is all that is necessary to give the distance without the aid of logarithms.* Thus if $l = 10$, $\frac{l}{\sin 1''} = 2062649$. Suppose the subtended angle is $3'$ then $d = \frac{2062649}{3 \times 60} = 11459$ feet.

Construction of a scale for laying off the distance.

19. A scale from which the distance may be taken off directly with dividers may be thus constructed. Draw an indefinite straight line as base, and from one extremity set off the following distances in inches,

† Tables of distances corresponding to the angles subtended by 20 feet and 10 feet bars have been prepared and can be obtained from the Surveyor General's Office, Calcutta.

* The error introduced by using this approximate formula is less than $\frac{1}{10}$ of an inch per mile.

1·15, 1·19, 1·23, 1·27, 1·32 &c., up to 11·46, these being the natural cotangents to radius ·01 of the subtended angles 30′, 29′, 28′ &c, up to 3′, beyond which it is unnecessary to carry it. At the point 11·46 raise a perpendicular equal in length to $\frac{10 \times \cot 3'}{5280} = 2{\cdot}17$ inches and join the extremity of this perpendicular to the other end of the base thus forming the hypothenuse of a right-angled triangle. Through all the points of division of the base draw perpendiculars terminating in the hypothenuse; these perpendiculars represent the distances corresponding to the respective subtended angles. These dimensions are for the scale of one inch to a mile, but the principle is applicable, *mutatis mutandis*, to all scales. It should be noted that if the bar is held horizontally, a difference of level between the observer and the bar does not prejudice the deduced distance, since the fact of the theodolite measuring angles on the plane of the horizon, makes automatically the necessary correction from the hypothenuse of the slope to its base. Another reason for using the bar placed horizontally, instead of vertically, is that the subtended angle is so much more easily measured in the former case by the employment of the two tangent-screws.

Means of aligning the bar.

20. The principle of this "bar-subtense" method requires that the bar should be held at right angles to the ray under measurement, and this is effected by means of sights made much after the fashion of gun-sights. A short iron bar about one foot long and about $\frac{1}{10}$ inch thick, carrying a V-sight at one end, and a bead at the other, is firmly screwed to the middle of the subtense bar; and so adjusted once for all that its sight-line is at right angles to the bar. The khalási who holds the bar lays it on the top of a plane-table stand so as to balance, and then revolves it until the sight-line of the iron bar intersects the observer's theodolite at the other end of the ray; he then holds it in this position until he receives a signal of some preconcerted kind from the observer to signify that the observation is completed. It is desirable that the khalási in charge of the bar should be well drilled in this work, as there is no check on him, unless the ray be short enough to enable the observer to see the sights himself, when looking through the theodolite telescope; this is generally possible up to three or four hundred yards.

Error caused by wrong alignment.

21. On the other hand it is worth noticing that the error arising from a slight misdirection of the bar is much less than would at first sight be supposed. For

if $\theta$ be the excess or defect from 90° of the bar's direction with the ray under measurement, the subtense measured becomes $l \cos \theta$ instead of $l$, and the resulting error in the distance is

$$l \cot s - l \cos \theta \cot s = l \cot s \times \text{vers. } \theta.$$

Now versine $\theta$ is about ·0001 for $\theta = 35'$, and therefore so long as the error in pointing does not exceed 35′—an almost impossible quantity, unless the bar be purposely misdirected—the error in measurement will not amount to $\frac{1}{10,000}$ part of the whole length, or about ½ foot per mile.

Plane-table sketching.

22. The surveyor having obtained his position on the table by one or other of the above methods, proceeds to draw rays to all objects, such as peaks, spurs, ravines, villages, &c., and to sketch in contours. He next proceeds to some other commanding station, where he again fixes his position, and again intersects the same objects, thus establishing their position on the board. The positions given by intersections of not less than 60° may be assumed to be correct; but when the intersections are more acute, only approximate; and they must be again intersected from some other more favourable station. Generally the position of any object should not be considered as finally determined, until tested by at least three rays intersecting at favourable angles.

Number of fixings per square mile.

23. In easy ground, free from jungle, four or five fixings per square mile should be sufficient to enable a practised plane-tabler to show all necessary detail: in more intricate country eight to twelve may be necessary. These figures refer to the 1-inch scale. In the case of larger scales or with inexperienced workmen, the numbers must be increased in proportion. Plane-table fixings are to be marked on the sections by small red dots. The actual number of plane-table fixings, and the average per square mile must be stated on each section in a foot-note.

D. O. No. 34, dated 29th June 1865.

D. O. No. 64, dated 25th May 1866.

When a surveyor finds himself in a position where he cannot fix himself by trigonometrical points, he may use any of his own so-called "plane-table points", which have been well tested by three or more rays.

Details to be shown on the field section.

24. On the 1-inch scale any natural feature, such as a ravine or watercourse, less than ⅛th of a mile in length, cannot well be shown; and if the country be intricate and full of detail, water-courses less than

¼th of a mile in length cannot easily be represented without creating confusion, and destroying the unity of the general effect. Ravines and intricate ground or hills of irregular formation are generally of little value, and do not demand such precision and minuteness of detail as more valuable land. In such wild tracts it is sufficient that the prominent features of the ground be distinctly shown; in this case watercourses of ¼th of a mile would hardly attract attention. It is customary to show by dotted lines such items as can, for cogent reasons, be only approximately surveyed. It is very necessary to pay attention to this rule, otherwise the surveyor may very possibly be blamed for bringing in incorrect work in country which he does not profess to have accurately surveyed, but merely sketched in roughly. and moreover users of the map might be misled if no clue existed as to what professed to be accurate, and what merely approximate, in the details shown. It must however be understood that recourse to dotted watercourses &c., should only be had when the necessities of the case *really* demand it, and not merely as a means of avoiding a difficult piece of plane-tabling.

D. O. No. 64, dated 25th May 1866.

*Continued*

25. The drainage system, defining the watersheds and watercourses, and also the outlines of table-lands, spurs, peaks, saddles or connecting links of ranges must be carefully laid down. All the important angles of streams and rivers must be fixed by actual survey if possible. Small villages are to be represented by means of tangents drawn from several surrounding plane-table positions so as to form polygons: large villages and towns to be represented by their actual shape as far as possible within the limits of the scale. The general figure and extent of cultivation, of waste and forest tracts, of groves and tanks, distinguishing especially irrigated rice fields—which generally display the contours of the ground—must be laid down. The areas of these are subsequently measured off by planimeter or talc square during the recess. The means of communication, whether by roads or tracks, must also be inserted.

Boundaries.

26. The survey of boundaries is a special operation, and one which varies so widely according to the locality under survey that it is difficult to lay down general rules for it. In the old topographical surveys in the native states, where any discussion on the site of a boundary was apt to raise disputes, and political difficulties, the practice was merely to survey them

as pointed out by village officials by ordinary plane-table fixings, and they have not generally been considered of much authority in consequence.

In more modern work where topographical surveys are largely concerned with forest reserves in British territories, it is customary to survey the boundaries with considerable care, frequently with theodolite and chain, leaving marks for the use of the detail surveyors. Trijunctions of villages and interior boundaries are also taken up and surveyed in detail; but much must necessarily depend on the special orders issued to the officer in charge when commencing the survey, by which he must be guided in such matters.

Means of securing proper junction with other sheets.

27. All villages, temples, or permanent objects adjoining, or outside of, the boundary of a topographical survey within a reasonable distance are to be fixed, so as to secure a good junction with the neighbouring maps. When the boundary of a survey is a river, *both* banks must be surveyed. Specimen cards showing the different symbols used for various boundaries may be had on indent from the Surveyor General's Office.

On the boundary of a district, as well as on all the edges of a full plane-table section, the survey should embrace an overlap of at least half a mile: this overlap is necessary to ensure a good junction with the maps of adjoining districts, and with adjacent sections respectively.

D. O. No. 64, dated 25th May 1866.

Erasures are not to be made on original plane-table sections, when discrepancies have to be adjusted, unless absolutely necessary.

Style of drawing.

28. Plane-table sections must in the first instance be drawn with pen and Indian-ink only; no washes or shades should be used. The first great rule in sketching ground is to give a proportionate amount of shade for corresponding steepness of slope. This shade must be obtained by greater or less closeness of contours, assisted by greater or less actual thickness of line; for deep shade cannot be satisfactorily obtained by thin lines close together.

C. O. No. 59, dated 16th November 1880.

Scale of shade.

29. Treatises have been written and rules given without end for so-called "scales of shade" suitable for actual practice in the field; but they have been all found impracticable, and the procedure now adopted aims chiefly at obtaining a similar style of drawing from all members of the Survey, so as to

make the various maps as far as possible comparable *inter se*; and abandons all attempts to represent certain definite slopes by any hard-and-fast system of hachures. These remarks apply chiefly to the 1-inch and smaller scales: on larger scales it is customary to lay down actual contours with the help of clinometers or water-levels, which of course define the ground more truly than any eye-sketching can do, though the relief obtained by this method is not very satisfactory. For a discussion on scales of shade, their possibilities and their drawbacks, the reader is referred to the Departmental orders marginally noted.

C. O. No. 59, dated 16th November 1880, also Note by Sur. Genl, dated 22nd June 1880.

30. The choice of delineating ground by the horizontal, or by the vertical, method of hachuring is not ordinarily left to the discretion of an executive officer, but it is as well that he should know the general arguments in favour of either system. It is chiefly a question of scale; the horizontal system best suits all scales over 1-inch to the mile, and the vertical system all scales below that limit, the 1-inch scale itself being perhaps equally good on either system. For reconnaissance work, exploration, and geographical surveys the vertical hachuring is far preferable, chiefly from the facility it lends to the delineation of hilly ground in an approximate way, without committing the draftsman to any details. If horizontal hachures are used, it is almost impossible so to draw the ground as to avoid the appearance of its having been actually surveyed, whereas vertical strokes can very easily be so employed as to merely convey the idea that the country is broken and hilly, but unsurveyed. For all engineering projects such as road-making, draining, tanks, railways &c., the superiority of horizontal contours is unquestioned.

Advantages of vertical and horizontal systems of hachures respectively.

31. At one time water-levels were much used in the Survey Department for laying out approximate contours to guide the eye-sketching, occasionally also reflecting levels, but these have now been entirely superseded by a very convenient and portable form of clinometer, by means of which the surveyor can measure the relative height of any object in view with regard to his own position, with the aid of only the simplest little calculation done on the spot. He can either deduce the height of his own position by observations to a point, whose height is known; or on the other hand if his own height is known, he can obtain the height of any other point in view within a reasonable distance. It is necessary of course to know the distance of the point

C. O. No 100, dated 8th February 1883.

observed, and this (which should not exceed three or four miles) is generally measured with dividers on the plane-table section.

Contouring with the clinometer and height indicator.

32. The instrument, of which a drawing and description are given in the order marginally noted above, stands on three ivory buttons and is placed on the surface of the plane-table. A small level is attached to the base-plate, and the instrument is so adjusted that, when made truly level, a line through the sight-vane to the zero of the object-vane is horizontal. Above and below this zero there is, on the one side of the object slit, a scale of natural tangents, and on the other a scale of degrees. To obtain the difference of height between his own position, and any other object in view, the observer looks through the hole in the sight-vane, after levelling the clinometer by means of the level on the base-plate, and notes what figure on the tangent-scale is cut by the ray to the object. This figure multiplied by the distance in feet gives the difference of height between the observer and the object in feet. For distances greater than two miles Table XVI of the Auxiliary Tables, 3rd Edition must be used, to correct the observations for curvature and refraction. The use of this instrument in contouring is much extended by a contrivance called a "Height Indicator" designed by Captain Wahab, R.E., which is employed as follows:—Suppose the surveyor, having fixed his position on the board, and found his height by observations to surrounding known points by the clinometer to be 2890 feet, wishes to lay down a contour at 2800 feet in the vicinity of his fixing. The contour lies 90 feet below him, and the clinometer will, in conjunction with the height indicator, enable him to lay down at once to scale the horizontal distance corresponding to 90 feet vertical interval, on the particular scale on which he is working. In the supposed case above, if on looking down the slope with his clinometer he finds the natural tangent to be (say) ·16, he will apply a pair of dividers to the height indicator along the ·16 line so as to intercept 9 of the sub-divisions on the left of the scale; this will give at once the required horizontal distance of the contour from the observer's position, if reduced to the proper scale of survey. The height indicator is designed for the scale of 4-inches to a mile. The distances of the contours next above and next below the observer's position being thus determined in several directions, the contour can be easily traced between the points thus found, and the operation is then repeated

D O. No. 16, dated 24th November 1887.

at subsequent plane-table stations. It is usual to distinguish, either by colour or by the quality of line, contours thus obtained from those inserted merely by eye, whose accuracy must necessarily be somewhat inferior. In parties in which large numbers of not very highly skilled native plane-tablers are employed, it has been found advantageous to entrust them with only the outlines of the detail survey, omitting the contours and sketching of the ground. A European surveyor subsequently inserts the contours on these plane-table sheets, thus ensuring the double object of accurate contouring, and a thorough examination of the section in the field; advantages which are cheaply gained at the sacrifice only of the small extra time required to go twice over the same ground.

Additional heights by clinometer and barometer.

33. The clinometer is much employed in obtaining heights scattered at intervals over the ground to supplement those given by the triangulation, and these are quite sufficiently trustworthy, when checked from two or three fixed stations, to be entered on the final maps. It can be used in places not easily accessible to the theodolite, and is most useful in fixing heights of obligatory points required for engineering works, necks of valleys, passes in ranges, junctions of rivers, inundation levels, &c., as well as in its more obvious application to peaks and plateaux, towns, cities, and temples &c. The introduction of the clinometer has to a great extent superseded the use of mercurial, or aneroid barometers in determining the heights of points not easily reached by the triangulation, as the results obtained by it, especially when checked from two or more points, are incomparably more trustworthy. There may, however, be cases when a barometer must be employed, and it is therefore desirable that topographical surveyors should be acquainted with its use.

It should be noted particularly, that unless the readings of a standard barometer within a reasonable distance at the sea-level, or at some known height, at the same time that the surveyor reads his own instrument, are available, no reliance can be placed on the result. Moreover the readings of the attached and detached thermometers must be recorded at the same time. With these data and a knowledge of the approximate latitude, the height may be determined by means of Tables XVII, XVIII and XIX of the Auxiliary Tables, 3rd Edition, explained at page 33 *et seq.* of the same work. The management of mercurial barometers is however notoriously troublesome when travelling, and their liability to accidents very great. Aneroid barometers are somewhat inferior to them in accuracy, but much more manageable, and are on

the whole to be preferred; but neither the one nor the other should be used where accuracy is aimed at. They, as well as boiling-point thermometers, are more suitable for the explorer than the topographical surveyor.

Large scale plans of cities &c.

34. All military cantonments, civil stations, large towns, forts or other places of importance falling within, or closely bordering on, the ground under survey must be specially surveyed on a large scale, which will be determined by the Surveyor General, to whom previous application for orders must be made, specifying the scale recommended to be employed, the area to be represented, and the probable extra cost, supporting the application with full reasons for requiring a large-scale plan, and also showing the views of the civil or political authorities on the question. These surveys should be on the scale of 12 inches = 1 mile at least, and must be as minute as possible, nothing being omitted which it is possible to show on the scale. It must be based on minor triangulation, the stations of which may be used as starting and closing points for traversing the roads and boundaries with theodolite and chain: a belt of environs one mile in breadth should be included in the survey. In large scale work of this kind, it will generally be found conducive both to accuracy and simplicity, to make a much freer use of chain measurements than on the 1-inch scale. Greater care is requisite in centering the plane-table over the points used. Traverses with chain and plane-table should be laid out in all directions for fixing the minor roads and foot-paths, small streams and other such details. These traverses require no computation, the directions being laid down by the sight-rule, and the distances plotted at once from a scale by dividers.

D. O. No. 386, dated 10th July 1876.

D. O. No 249, dated 9th March 1871.

*Continued.*

35. The names of all public buildings, roads and mahallas are to be inserted on the plan; also boundaries of cantonments and municipalities. The names of tanks, temples, streams, mosques, gardens &c., should be ascertained, and either recorded on the body of the plan, or given with corresponding numbers in a blank space as marginal references. If the subject be too large to be embraced conveniently on one sheet, it must be worked in sections; and the greatest care must be taken to make the common lines of junction agree precisely. A small index must be drawn on the title section or other blank space showing distribution of the sections. Colour may be used on the field plan with.

Ditto.

advantage, but the fair copy must be drawn in pen and ink, and in such a style as to be suitable for photo-zincographic reproduction. Specimens of topographical items such as grass, trees, sand-hills, railways, telegraphs &c., will shortly be published, and will be available by indent on the Surveyor General's Office.

Use of rectangular co-ordinates.

36. For large-scale surveys of this kind, rectangular co-ordinates instead of spherical, will generally be found more convenient, especially where there is much traverse work. There is but little difficulty in passing from one sytem to the other by means of Tables XXVIII and XLII in the 3rd Edition of the Auxiliary Tables; still it may be as well to give an outline of the procedure here, to assist officers who have never been called upon to combine the two systems.

In all topographical surveys embracing a large extent of country, when rectangular co-ordinates are used, the centres of each square degree are taken as independent origins, and the traverses in each are worked quite independently of the neighbouring degrees. Consequently within the limits of one square degree no ambiguity can arise as to the method of plotting stations and traverses. Supposing there to be a network of G. T. triangulation, or of 1st class topographical triangulation, extending over the degree, the first step is to reduce the spherical co-ordinates (supposed to have been previously computed) into rectangular co-ordinates measured from the centre of the degree by aid of Table XXVIII of the Auxiliary Tables. The latitudes and longitudes of the stations of the minor triangulation need not be computed, it will suffice if the distances are calculated in Form P. 14. They may then be considered as simply traverse stations based on the principal stations, and their rectangular co-ordinates may be computed in traverse form by their relative distances and azimuths.

Adjustment of spherical with rectangular co-ordinates.

37. As however the margins of plane-tables, as well as the fair maps must, for the sake of fitting together, be made to conform to meridians and parallels, Table XLII of the Auxiliary Tables has been compiled, by the aid of which the corners of the spherical graticule may be plotted, and the graticule itself drawn. The plane-table sections are completed up to the margin of the spherical graticule, (with the proper overlap) and thus no difficulty is experienced in piecing the map together. A network

of rectangular co-ordinates must thus precede the spherical graticule, and provides the basis on which the latter is formed.

Projecting from different origins.

38. In projecting points near the margins of plane-table sections it frequently becomes necessary to plot them by co-ordinates from the origin of a neighbouring degree, and not from that of the degree in which they are situated. The formula by which this is done is as follows:—

Let $x_a$, $y_a$ be the co-ordinates of a point referred to centre of degree $a$, as origin, $x_b$, $y_b$ the required co-ordinates of the same point referred to centre of degree $b$.*

Let $l$ be the length of the perpendicular to the meridian passing through $a$, intercepted between $a$ and the margin of the degree, $m$ the meridian distance between the two origins, and $C$ the angle of convergence between the meridians at $a$ and $b$.

Then
$$x_b = l + (x_a + l) \cos C - y_a \sin C$$
$$y_b = m + (x_a + l) \sin C + y_a \cos C.$$

These equations are general and apply to all cases, but in using them strict attention must be paid to the signs: the following hints may be found useful.

If the degree to which the new origin appertains, with regard to the old one, lies (contiguously)

| | |
|---|---|
| N.W., W. or S.W., | $l$ is + |
| S.E., E. or N.E., | $l$ is − |
| N. or S. | $l = 0$ C $= 0$. |
| S.E., S. or S.W., | $m$ is + |
| N.W., N. or N.E., | $m$ is − |
| E. or W. | $m = 0$. |

The linear quantities in these equations must all be expressed in the same unit, but it is immaterial whether this be feet, links, yards or any other unit. When a continuous traverse runs from one degree into another, the co-ordinates of its stations may be all computed from the

* Co-ordinates are considered *positive* to the north and east of the origin, and *negative* to the south and west.

origin of the degree in which it starts; unless it encroaches far into a neighbouring degree, in which case the part falling into each of the degrees should be referred to the centre of that one as origin.

Village books and other statistics.

39. The register of village names and other details must be kept in Form P. 29, and filled up daily in ink. The number of houses must be obtained as accurately as practicable from the village officials. It is usual in estimating population to allow six inhabitants to each house. Topographical surveyors have generally many opportunities of collecting statistics about the country under survey, and it is most important that they should avail themselves of such chances, especially in Native States and little-known districts. Full information on this point is given in an Appendix to the "Manual of Surveying for India," page XLII, to which the reader is referred. The officer in charge of the party should impress upon his assistants the great value of information of this kind when intelligently collected and systematized. A special report on all fords, ferries and passes of any importance is to be drawn up and forwarded to the office of the Quarter-Master General for record.

C. O. No. 133, dated 11th March 1884.

D O No. 229, dated 26th July 1870.

Orthography of native names

40. The proper transliteration of native names into English must be carefully attended to. For most parts of India lists of names showing the proper spelling have been circulated by order of the Government, but these lists cannot embrace every name that the surveyor will meet with, and consequently he should be conversant with the system in use.

Dr. Hunter's rules, which are nearly identical with those promulgated many years ago by Sir William Jones, are now almost universally adhered to. The basis of the system is that the vowels in the English transliteration have the same sound as in Italian, and the consonants the same sound as in English; but there are small modifications to this broad rule. Complete instructions for carrying out the system are given in the "Manual of Surveying for India," Appendix, page CXCII. It happens unfortunately that this system is largely dependent on accents for the proper pronunciation of names; and it has always been found in mapping a most difficult task to write the accents so as to be easily and immediately visible, as they are almost sure to become mixed up with hill-shading and other details.

D C. No. 23, dated 30th October 1873.

C. O No. 160, dated 1st November 1884.

Names on field-sections to be hand-printed.

41. All names, whether of villages, districts, hills, rivers, &c., must be hand-printed on the original field sections: type is reserved for the fair maps only. This rule is laid down in order that the art of hand-printing, a very useful accomplishment in a surveyor, may be sufficiently studied. The places from and to which roads, when they pass out of the section, lead, must be printed in the margin. If the word used is "from" it signifies that the place named lies towards the left-hand, or beginning of the name written, and if "to" that it lies towards the right. This distinction is important.

R. S. D. dated 1st June 1850.

Incomplete sections.

42. If for any reason a surveyor has to leave his section unfinished, he must be careful to make the edges conform to parallels and meridians, and not to an indefinite or broken line. Such a boundary as this latter makes the subsequent joining up difficult and uncertain.

D. O. No. 346, dated 2nd February 1875.

Re-magnetizing compass needles.

43. A good compass that is fairly sensitive and plays freely, is a great aid to rapid plane-tabling, inasmuch as it enables the surveyor to set his plane-table so correctly, that the intersections of the rays to the surrounding points give him at once his true position, without the necessity of a second approximation. In order to magnetize needles when one pair of magnetic bars is available for the purpose, draw the southern pole of one bar along the northern pole of the needle from the centre outwards, taking care to keep the bar revolving in a continuous swing—that is, the bar should not be rubbed backwards and forwards along the needle—and draw the northern pole of the other bar along the southern pole of the needle.

When two pairs of magnetizing bars are available, place one pair in a line on a table at a distance apart of about $\frac{1}{3}$ of the length of the needle to be magnetized, the northern pole of one bar to be towards the southern pole of the other. lay the needle to be magnetized so that its southern pole shall fall on the northern pole of one bar, and its northern pole on the southern pole of the other bar; take the two other bars and draw them over the needle from the centre outwards in such a manner that the northern pole of one shall be applied to the southern pole of the needle, and *vice versâ*. In packing magnetic needles, or whenever they are out of use, great care should be taken that a continuous flow of the magnetic current may be kept up. Thus the boxes

containing the needles should be laid alternately with the northern poles pointing in opposite directions; moreover sudden and violent blows or jars should be avoided as tending to weaken or destroy the magnetism of a needle. The magnetizing bars themselves also, when not in use should be so placed as to have the north pole of one towards the south pole of the other, and the armatures attached to them. If a telegraph office be anywhere at hand, a needle may be easily remagnetized by obtaining the use of a few battery cells, and passing the current through the needle. Needles, when not in use, should be thrown off their pivots by the lever provided for this purpose: this should always be done whenever it is taken off the plane-table.

## SECTION IV.—EXAMINATION AND CHECKING OF PLANE-TABLES.

Checking field work.

1. Not the least important of the duties devolving upon the officer in charge of a topographical party is the examination and checking of the plane-tables of his assistants. The methods by which this can be carried out are various, and the choice must be left to the discretion of the officer himself. In open country, tolerably flat and unenclosed, a check-line measured with a perambulator* is as rapid and accurate a method as any. The plane-table should be set up somewhere near the edge of the ground to be tested, and the position carefully fixed by the surrounding trigonometrical points. The perambulator may then be started off in a bee-line through the work, its readings being recorded where the line passes any features on the ground, until it is desirable to change the direction. The plane-table is then set up again, the distances plotted, and compared with the work thereon, and then a new line being chosen, the process is repeated as often as necessary. Rays should be taken to neighbouring villages, hills, streams &c., whenever the table is set up. In hilly ground the use of the perambulator is impossible, and chaining is too slow except for small areas. The examiner must then content himself with numerous fixings of the board, checking the positions of the hill features by rays, and noting whether the sketching adequately represents the ground. In dense forest testing can only be done by chaining, and is at best but a very slow process.

D. O. No. 3, dated 16th March 1863.

* A description of this instrument, and the method of using it, will be found at page 46 of the Manual of Surveying for India.

It is a good rule, and one that should be adhered to as far as possible, that no plane-table should be considered complete, unless it has been tested in the field by competent authority. Remarks on the examination of original plane-tables in the field should be recorded on them, and signed by the examiner as it is of much importance to place this permanently on record.

B. O. No. 35, dated 4th June 1879.

D. O. No. 3, dated 16th March 1863.

Checking of field work.

2. There is no objection to employing experienced surveyors, and assistant surveyors, in testing the work of the sub-surveyors; in fact such a division of labour is imperative in a large party, as the officer in charge would find it impossible to do all the checking work single-handed in addition to his other duties. Discrepancies of any importance should be thoroughly examined on the spot, and it should be ascertained as far as possible whether they are the result of inexperience on the part of the plane-tabler, or deliberate shirking; as in the latter case very heavy penalties are liable to be incurred. Falsification of work is one of the gravest offences a surveyor can be guilty of, inasmuch as it brings discredit on the Department, and may throw suspicion unjustly upon all maps turned out by it.

D. O. No. 64, dated 25th May 1866.

Accuracy and fidelity are all-important.

3. It cannot be too strongly impressed on all members of the Department, that every consideration should give way to the one great and paramount object of turning out good work, which may be thoroughly relied on by the public, and which will be found on examination in the field to be as accurate as it appears to be when turned out of the hands of the skilful draughtsmen who execute the final maps. The public service requires the maximum amount of work of the best description; it expects quantity as well as quality; but quantity without quality is of very questionable value, and may mislead and become detrimental; the outturn should, therefore, on no account be permitted to exceed what can be accomplished with an appropriate degree of fidelity. The surveyor should resist all temptations to gain fictitious credit by departing from the strict line of duty that is clearly marked out before him. It may be difficult for him to refrain from injudicious haste when he knows that some of his brother surveyors are working with greater rapidity than himself, and are likely to gain more credit than he does, because they happen to have a greater show of work. But his duties appertain to his own work only, and if he is careful to make it as good as possible, it will always be a credit to him, and to those who are associated with him.

D. O. No. 34, dated 29th June 1865.

D O. No. 64, dated 25th May 1866.

Miscellaneous duties of officer in charge.

4. Although triangulation and the examination of plane-tables may be considered the peculiar province of the head of the party, yet he should take a leading share in every part of the duties in the field and in recess. He should instruct his subordinates in the use of instruments, in drawing and in mapping. No pains should be spared in training newly-joined assistants in the theory as well as in the practical use of the theodolite and the plane-table.

He should see that his subordinates are properly equipped with instruments and instructions; also that they keep up a sufficient amount of carriage to move daily, or march at a moment's notice, on which condition only the daily travelling allowance can be claimed; and that they are fully capable of performing their work in the field. He should be careful of the due preservation of the health of his establishment, and should see that they are acquainted with and act upon the well-known rules for guarding against fever and other diseases in malarious tracts. In Chapter III of this Hand-book will be found some remarks on the sanitary arrangements for survey parties by Sir Andrew Waugh. He should keep his establishment duly informed of the various orders emanating from the head-quarter's office, by circulating all departmental orders and circulars as convenience and necessity may dictate.

D. O. No. 15, dated 17th March 1864.

## CHAPTER II.

# Duties in Recess.

### SECTION I.—COMPUTATIONS.

D. O. No. 86, dated 14th September 1866, modified.

Completion of angle books.

C. M. No. 156, dated 16th October 1884.

1. It is most desirable that the Abstract of Horizontal and Vertical Angles, and all other details of the angle books, including paging and indexing, should be written up, examined, and signed during the field season, as the work progresses; but if for any reason this has not been possible, it should be taken in hand the first thing on return to recess quarters, before any of the computations are begun. Most scrupulous attention must be paid to neatness and methodical arrangement of all records and computations. Good handwriting and freedom from blots, erasures, and interlineations are essential. Angle books and computation volumes should be supplied with title pages in which are given

1. Description or title of volume.
2. Name of department.
3. „ and number of survey.
4. „ of observer.
5. „ of executive officer.
6. „ of Superintendent or Deputy Surveyor General.
7. „ of Director or Surveyor General.
8. „ Season.
9. Number of degree sheet, or name of country.
10. Name of recess station and date on the left hand, and signature, rank and title of executive officer on the right.

They must also be paged and indexed. It must be remembered that each of these volumes is but one amongst hundreds deposited in the Head Quarters offices, and that every endeavour should be used to make it as easy of reference as possible by placing printed labels on the outside, both on the back and on the sides. All computations must be done in duplicate by two independent computers who should use different sets of tables, and each copy must be signed by both computers.

Arrangement of triangles.

2. The order of succession of the 1st class secondary triangles, which should be written on Form P. 13, should be arranged by the officer in charge of the party, as it requires considerable judgment to do this in the most efficient and convenient way. The order in which the names of the stations of each triangle are entered should always be round in the same direction as the hands of a watch, so that any one standing at the first station and facing in the direction of the other two should have the second one towards his left hand, and the third towards his right*; the distance between the first and second stations forms the given base. The filling up of the form is too simple to require detailed explanations. The triangular error is divided equally between each of the three angles of every triangle; it is equal to the difference between the sum of the observed angles and 180° + spherical excess, with the proper sign. The angles observed, as well as the corrections, and the angles for computation, should be retained to the nearest tenth of a second: the lengths of sides in feet should be taken out to tenths, and in miles to thousandths.

Secondary and tertiary triangles.

3. The minor triangles are entered in Form P. 14 to which the above remarks also apply, with the exception that the spherical excess is not computed, and the angles are entered to the nearest second only. The lengths of sides in feet should be taken out to units, and in miles to thousandths.

The intersected points, or Tertiary triangles, are contained in Form P. 15; in these the third angle is nearly always unobserved, and its value is supplementary, *i.e.*, it is obtained by taking the sum of the first two angles from 180°. The majority of these points should be fixed by observations from at least three stations, otherwise no reliable check on their identification exists. If however the *height* of an intersected point is observed from two stations, the accordance of the two results furnishes a test, though not a very rigorous one, that the same point is observed from both: the test is the more reliable, the steeper the rays to the point observed. If a point P be observed from three stations A B C, two triangles A B P and B C P may be computed, giving a double value of the side B P, the agreement of which will furnish a test of the accuracy of the work. In such cases it is useless to compute (as has sometimes been done) the triangle A C P, no new information being

* This rule ensures the correct plotting of the points, if laid down by distance only.

obtained thereby. The lengths of sides in feet should be computed to units and in miles to thousandths.

Limits of errors of triangulation.

4. Linear errors of 1st class secondary triangulation should be less than 3 inches per mile, and triangular errors less than 2 seconds. In minor triangles these errors should not exceed 6 inches, and 5 seconds respectively: for intersected points, the linear error will largely depend on the kind of object intersected, if it be a pole, or tree stem, or temple, or other well-defined object, the error should average perhaps about 1 foot per mile.

D. O. No. 346, dated 2nd February 1875.

Method of deducing linear errors of triangulation.

5. In deducing the linear errors of the triangulation, the mean of all the values of the same side is to be taken as the correct value, and the differences between that mean and each separate value would be the linear errors in each case, which are to be used in calculating the general mean linear error for each class of triangles. There is a more direct method of deducing the same thing from the log. sides only, which though not rigorously correct in theory is probably more accurate in practice, owing to the feet being given only to the nearest tenth. The method is as follows:—Take the mean of the logarithms to represent the correct logarithm of the side, subtract each logarithm from this mean; take the mean of the differences and treating it as a whole number, divide by 68; the result is the linear error in inches per mile. Thus suppose the three logarithmic values of a side to be 4·8149322, 4·8147443, and 4·8147559. the mean is 4·8148108. The differences between this and each of the logarithms are ·0001214, ·0000665, and ·0000549, the mean of the three being ·0000809, then the average linear error in inches per mile will be $\frac{809}{68} = 11{\cdot}9$.

Computation of latitudes, longitudes and azimuths

6. The computation of Latitudes, Longitudes and reverse Azimuths should be next undertaken. The forms used are P. 16 for 1st class stations, P. 17 for secondary stations, and P. 18 for intersected points. They differ only in the extent to which the computation is carried. The first two are explained at considerable length, with examples, at pages 14 to 18 of the 3rd Edition of the Auxiliary Tables: it is important to note that the angles for computation, increased by $\frac{1}{3}$ of the

spherical excess, commonly called *spherical angles*, must be used in this computation for 1st class stations: for minor stations and intersected points, the difference between the angles for computation and the spherical angles is immaterial and the former may be used. Form P. 18 is merely an abbreviated form of P. 17, and suffices for intersected points. In Forms P. 16 and P. 17, the computer should be guided by the examples as to the number of decimal places to be retained; in Form P. 18 λ and L require only one place.

7. The latitudes, longitudes, azimuths and sides contained in the foregoing computations must now be entered in the Synopsis P. 24. Care should be taken that every side which has been computed be entered, and that no side should appear twice; that where mean values are obtainable they should be entered, and that the numbers of the triangles from which the values have been obtained, be recorded in the appropriate column. The height contained in the last column is calculated subsequently. This compilation will then be a complete synopsis of bases, the values of which will correspond with those given on the charts of triangulation to be described hereafter.

D. O. No. 346, dated 2nd February 1875.

Synopsis of latitudes, longitudes, azimuths and sides.

8. Before passing on to the Computation of Heights, it will be as well to mention here three other forms of computation which are occasionally required. The first is the calculation of the length of the third side of a triangle when the angle opposite to it, and the two sides including that angle, are given. The form for this is P. 25, in which AC and BC are the two known sides, including the known angle C, from which the value of AB has to be determined. To those who have an elementary knowledge of Plane Trigonometry, a detailed explanation of the working of this form is superfluous. The second is the computation of the position of a station from observations to three known points by Form P. 26, the correct working of which may be gathered from the notes at the foot of it, and the third is the computation of the distance apart, and mutual azimuths of points, whose latitudes and longitudes are known. For this purpose there are two forms *viz.*, P. 27 and P. 28, the former for principal stations, and the latter for secondary. The explanation of these computations will be found in the Auxiliary Tables.

Miscellaneous computations.

C. O. No. 73, dated 7th October 1881.

C. O. No. 114, dated 7th August 1883.

Satellite stations.

9. It has been remarked in Chapter I, Section II, para. 12, that it occasionally becomes necessary to use a so-called "satellite station". There are two cases which may occur (1) that in which a satellite station is observed *to*, and (2) that in which a satellite station is observed *from*. The first generally arises from some object near the mark being accidentally observed instead of the mark itself, the mistake being discovered on visiting the station; or from the mark being so difficult to see that some better defined object very close to it is purposely intersected in its stead. All that is necessary in this case is to measure carefully with a tape the distance between the satellite, and the true mark, and the angle at the latter point between the satellite and the distant station, from which the original observation was made. This angle need only be recorded to the nearest minute. The computation is as follows; in the annexed diagram let A be the station from which the satellite S was observed instead of the true mark C. Let CS = d, the angle SCA = $\alpha$, SAC = $\theta$, and the perpendicular SP from S upon AC = p, AC = a.


Then $p = d \sin \alpha$, and $\tan \theta = \frac{p}{PA}$.

Now as SC is very small in comparison with AC, and the angle SAP also very small, we may put PA = AC and $\tan \theta = \theta'' \sin 1''$,

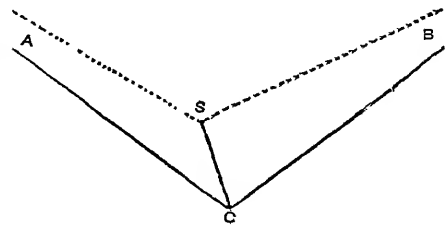
hence $\theta = \frac{d \operatorname{cosec} 1'' \sin \alpha}{a}$.

The value of a may be computed with quite sufficient accuracy from any triangle in which that side occurs, using two observed angles only, the third being supplementary. Hence the correction to any angle in which S has been observed instead of C is $\frac{d \operatorname{cosec} 1'' \sin \alpha}{a}$ with its proper sign.

*Continued.*

10. The second case, *viz.*, that in which a satellite station is observed from, generally occurs from an obstacle hiding the view of some particular station which it is necessary to observe, and which can be avoided by shifting the instrument a few feet one way or the other. Let ABC be any triangle in which the angles BAC ABC have been, or can be observed, but the angle ACB cannot be measured owing to an obstacle preventing

the theodolite being set up at C. Suppose the theodolite to be moved to S, it is required to compute the correction to the observed angle ASB in order to reduce it to ACB. Four cases may arise according to the position of S with regard to AC and BC. It may lie between them, as in the figure, or between AC and BC produced, or between AC produced and BC, or between AC produced and BC produced. With a little care however with regard to signs one formula may be made applicable to all cases. When the observer has set up his theodolite at S, he must first measure carefully with a tape the distance SC, and then having set the limb to read 0° 0′ he must turn the telescope on C, and then revolving it from left to right record the readings of A and B. This completes the observation. To compute it, the length of AC and BC must be first calculated by using two angles only of the triangle ABC. Let AC = b, BC = a, SC = d, the theodolite *reading* of A = $\beta$ and of B = $\alpha$.




Then it may be readily shown as in the first case that the magnitudes of the angles SAC, SBC, in seconds—apart from all consideration of signs—are

$$\text{SAC} = \text{d cosec } 1'' \frac{\sin \beta}{\text{b}}, \quad \text{SBC} = \text{d cosec } 1'' \frac{\sin \alpha}{\text{a}},$$

and the total correction to the angle ASB becomes

$$- \text{d cosec } 1'' \left\{ \frac{\sin \alpha}{\text{a}} - \frac{\sin \beta}{\text{b}} \right\}.$$

This formula will apply to any of the four positions of S specified above, if it is remembered that the sines of angles between 180° and 360° are negative, and the sines of $\alpha$ and $\beta$ are treated in accordance with this property.

If three or more rays from S are to be considered, the same procedure can be extended to them, but such cases are of infrequent occurrence, and it is unnecessary to give further details.

Computations of heights.

11. The computation of heights of principal, and secondary stations, is fully explained with numerical examples at pages 24 to 31 of the Auxiliary Tables, to

C. O. No. 52, dated 14th June 1880.

which the reader is referred. The form used for both is P. 19: for principal stations the heights should be retained to tenths of feet, and for secondary stations to units only. Refraction can only be computed in the cases where there are reciprocal observations between the stations. Form P. 20 provides for the computation of heights of intersected points. In connection with this form Table XV of the Auxiliary Tables is required, the adopted refraction with which to enter the table being obtained from the computations in Form P. 19. If no refraction be forthcoming, it is usual to take it as $\frac{1}{15}$ or 0·07 of the contained arc. Clinometric heights, which are generally computed in the field by the plane-tabler for immediate use in running approximate eye-contours, are worked out in Form P. 21, which is too simple to need explanation.

C. O. No. 121, dated 19th October 1883.

C. O. No. 55, dated 22nd September 1880.

12. It is occasionally necessary in topographical work to determine the azimuth of a ray by recourse to astronomical observations, especially where traverses are employed. The most accurate method of obtaining this is by observations to a circumpolar star at elongation, as explained in Chapter VII, Part V of the Manual of Surveying for India; this method is, however, too laborious for general application in topographical work, and the alternative, given in the order marginally noted, is much to be preferred. It consists essentially in measuring at one and the same instant (1) the angle between a selected star and a referring mark, and (2) the star's altitude. Practically this is effected by allowing the star—by working the tangent-screws of both the horizontal and vertical clamps—to transit the spot where the vertical and horizontal wires of the telescope cross; both limbs are then read off and recorded, and subsequently the reading of the limb when the telescope is directed to the referring mark. This constitutes the whole observation, which must be repeated with the usual changes of face. A knowledge of the latitude and the star's declination is required for the computation; moreover, it is desirable that the star should be nearly E or W of the observer, and not at a very great altitude. Form P. 33 is employed for this computation.

Observations for azimuth.

13. As the survey progresses it becomes necessary to record all the computations connected with it in some readily accessible form; and it has been found by experience that the best means of accomplishing this is to collect them into volumes entitled "General Reports," each of which contains the

General reports.

records of an area 1° of latitude by 1° of longitude, or one *square degree* as it is commonly called. These volumes contain only a summary of the calculations, and are eventually destined for deposit in the Head Quarters Office: of the two original sets, one, completed to correspond as far as possible with the general report, is sent to the Surveyor General's Office, and the other retained in the office of the survey party. C. O No. 41, dated 23rd September 1879 C. O. No. 133, dated 11th March 1884.

14. The general reports should be arranged under the following headings, as nearly as may be conveniently practicable in each instance:— C. O. No. 41, dated 23rd September 1879.

Arrangement of general reports.

I. Chart of triangulation with numerical data.*

II. Title page. Form $\frac{\text{G.R.}}{1}$.

III. Table of contents. Form $\frac{\text{G.R.}}{2}$.

IV. Introduction.

V. Description of the general construction of the stations and marks erected for observation.

VI. 1st Class Secondary Triangles. Form $\frac{\text{G.R.}}{3}$.

VII. Minor Triangles. Form $\frac{\text{G.R.}}{4}$.

VIII. Abstract of horizontal angles, azimuths and sides, with descriptions of stations and points. Form $\frac{\text{G.R.}}{5}$.

IX. Abstract of vertical angles, and differences of heights. Form $\frac{\text{G.R.}}{6}$.

X. List of latitudes, longitudes, and heights of all trigonometrical stations and points. Form $\frac{\text{G.R.}}{7}$.

XI. List of latitudes and longitudes of centres of towns, and villages. Form $\frac{\text{G.R.}}{8}$.

* This is a photo-zincographed copy of the chart described in the next section.

XII. List of rectangular co-ordinates of traverse stations and points. Form $\frac{G\,R.}{9}$.

XIII. Skeleton chart of traversing.

XIV. General abstract of village lists &c., by standard sheets. Form $\frac{G.R.}{10}$.

XV. Abstract of village lists &c., by degree sheets. Form $\frac{G.R.}{11}$.

By a *station* is meant any permanently marked structure, at which observations have been taken with a theodolite; by a *point* is meant any other object fixed by the triangulation at which a theodolite has not been set up.

C. O No. 41, dated 23rd September 1879.

Title page.

15. The title page should specify the name of the survey, the degree in latitude and longitude to which the report refers, and the years during which it was in progress.

Ditto.

Introduction.

16. The Introduction should give a full account of whatever may be necessary to enable the contents of the volume to be readily understood. It should quote the fundamental elements on which the triangulation was based, specifying whence they were obtained, and whether from final or preliminary data of the Great Trigonometrical Survey, whether traversing has been added to the triangulation, and rectangular co-ordinates employed as well as spherical: it should give full information regarding the positions of the adopted origin, and the initial meridian of the rectangular co-ordinates; also full information regarding any spirit-levelling, which is incorporated with the operations. It should also give a sufficient description of the physical geography of the country comprised within the degree—stating whether it is level or hilly, smooth or rugged, open or forest-clad—in order to explain any peculiarities of the triangulation; and it should add any information which is likely to be serviceable to surveyors who may have occasion hereafter to visit the country, in order to re-survey any portion of it on a larger scale, as may occasionally be necessary for special purposes. Finally it should state the names of the persons by whom the work within the degree has been chiefly performed.

17. The descriptions of the general construction of the stations, and of the signals at unvisited points, are intended to obviate the necessity of frequently repeating these details in the descriptions of the stations and points. A description of each class of structure should be given here, and numbered for reference. C. O. No. 41, dated 23rd September 1879.

Description of stations.

In the description of the stations, which should be entered at the top of the form of Abstract of horizontal angles, a reference should be for class of structure under heading V, and full details given of the locality in which the station is situated; this is necessary in order to facilitate ready identification hereafter. The points which have been observed, but not visited, are usually poles, trees, or other objects, which have no name and require no description further than a reference to their class under heading V; in some cases, however, the object may be a temple with a name, or one of a group of domes or spires, which must be particularised for future identification: when this is the case a lucid description of the object should be given.

18. The method of preparing the Abstract of horizontal angles is explained in Chapter I, Section II, para. 25, and it is only necessary to add here that each class of station observed, *viz.*, principal, 1st class secondary, minor and intersected, should be entered as a separate group, with a small space intervening for the sake of clearness. Ditto.

Abstract of horizontal angles.

19. In filling up Form $\frac{\text{G.R.}}{6}$ particular attention should be paid to entering in the column of remarks any necessary details regarding the level of the object observed, with reference to its surroundings, which may be of value hereafter. For example if the point is on a bridge, or beside a river, or on the edge of a well, its height above mean level of the water in its vicinity should be given; information of this nature is frequently of much interest, even if only roughly obtained, and when obtained it should be prominently recorded. Ditto.

Abstract of vertical angles.

20. In Form $\frac{\text{G.R.}}{7}$ it conduces to clearness if the *stations*, in contradistinction to the *points*, are underlined, so as to catch the eye readily. Ditto.

List of latitudes, longitudes and heights of stations and points.

C. O. No. 41, dated 23rd September 1879.

21. Form $\frac{\text{G.R.}}{9}$ should only give the permanently marked traverse stations and points—such as the trijunction pillars of village boundaries, and other objects which may be readily identified hereafter—but no unmarked theodolite stations. Its arrangement may be either alphabetical, or numerical following the courses of the traverses, as may be considered most desirable.

List of rectangular co-ordinates.

The skeleton chart of traversing should be prepared on the smallest scale consistent with the clear presentation of necessary details.

C. O. No 133, dated 11th March 1884.

22. In the recess-season, if complete lists of villages can be obtained from the civil authorities, corrections to the names obtained in the field should be made. The examination of latitudes and longitudes for seconds should be carried out in office by a sub-surveyor, and that for minutes and tens of minutes by inspection only, by running the eye over the field sections, and judging whether the figures correspond with the positions on the graticule: the examiner should initial the village books after testing. The field lists having been duly checked the names must be arranged so as to serve as gazetteers of the standard maps, sheet by sheet, after the manner of the best maps of the day; for this purpose $\frac{\text{G.R.}}{10}$ is provided. If parganas or tahsíls have been shown complete as to their boundaries on the maps, then pargana lists must be kept complete and separate; and an alphabetical arrangement must be made out for each pargana. If not then for each state, or other division, the names of the parganas being simply entered in the appropriate column, the villages being placed alphabetically in Form $\frac{\text{G.R.}}{8}$.

Treatment of village lists.

This having been done and the number of villages entered on each page of the standard gazetteer, the number of houses and of inhabitants should be totalled page by page, and grand totals be entered at the end of each pargana or state list.

Ditto.

23. The areas in square miles must be entered on the last page of the standard gazetteer for each pargana or state, so that the sum total of cultivated, cultivable, waste, and forest lands may exactly agree with the computed areas of the graticule of the standard sheet.

Areas of parganas and states.

The standard gazetteer of each sheet having been made complete, it remains to combine all of them in a tangible form, so that the information thus obtained may be made easy to refer to by entering details in an abstract form, degree sheet by degree sheet. This abstract is to be incorporated in $\frac{\text{G.R.}}{11}$ in the general report of the degree sheet to which it appertains.

24. It should be remembered that the simplest plan of arranging names alphabetically, is, in the first instance, to write the whole of the names consecutively, in any order that may be most convenient, on a sheet of paper; then to cut up the paper, so as to have each name on a separate slip; afterwards it is easy to shift the slips about on a table, until the names are brought into alphabetical order. C. O. No. 41, dated 23rd September 1879.

Method of sorting names.

25. The size of a leaf of manuscript for the general report should be the same as the present printed forms for 1st class triangles, *viz.*, 15 inches × 11·1 inches, with a margin of exactly 1·15 inches left inside for binding, and marginal space of 1¾ inches at top. The breadth of the form or space written on should be 8·6 inches, the length 12 inches, leaving the remainder as margins at the outside and the bottom. Ditto.

Sizes of pages of report.

## SECTION II.—MAPPING.

1. The paper on which the standard fair maps are to be drawn, must be carefully selected, as much of the success in photo-zincographing the sheet depends on the paper being perfectly white, smooth, clean, and free from wrinkles and blemishes of all kinds. It should not be mounted on cloth. Suitable paper may be obtained on indent from the Calcutta office. C. O. No. 101, dated 10th February 1883.

Choice of paper.

There is a method of partially restoring damaged drawing paper, which it may be useful to know on certain occasions; but where good paper can be obtained in the first instance, it is much to be preferred to any thus doctored. It is as follows:—

Take a wash composed of 1 drachm of isinglass steeped in 2 oz. of water for 12 hours, and simmer it for 15 or 20 minutes over a fire. When nearly ready add of common alum (phitkari) in powder C. O. No 64, dated 14th June 1881.

20 grains, strain through linen for use, apply it when the paper is on the drawing board and damp, and work it on with a flat brush; when dry, wash the paper over with water, which will indicate by the absence or otherwise of spots, whether a second wash of the above is necessary. When the paper is thoroughly recovered, wash it well with plain water, and a flat brush, to take off any superfluous isinglass, absorbing the water with a clean linen rag. This treatment may be applied to a sheet of paper on which a map has been already begun, if the precaution is taken of laying it face downwards on a clean table and securing the edges by pasting slips of paper round them, and applying the above solution carefully to the back only. Experience shows that when thus treated the graticule is little, if at all, distorted.

C. O No. 153, dated 6th October 1884.

Projection and tracing.

2. Each standard sheet (on the 1-inch scale) should be projected for 15 minutes of latitudes, and 30 minutes of longitude, irrespective of the amount of drawing to be entered on it. For the scale of 2 inches = 1 mile, the dimensions will be half of the above quantities, and so on in proportion for other scales.

If the original work on the plane-table sections has been projected by spherical co-ordinates, the standard map graticule may be similarly projected by the use of the appropriate numbers in the Auxiliary Tables. If rectangular co-ordinates have been used in the field work, Table XLII must be employed for obtaining the positions of the corners of the spherical graticule. The graticule should then be sub-divided into five-minute squares so as to enable the draftsman, when tracing, to disperse the differences that are sure to be found between the graticules of the field sections and the fair projection.

The next step is to project, by the appropriate scales, all triangulated points with the greatest possible accuracy. The paper may then be affixed to the tracing-glass, with the field sheet properly adjusted under it, and the tracing of all details completed in pencil on the fair map square by square. Village sites and trigonometrical points may then be inked in, using the authorized symbols, and then the typing of the names (except province and district names) should be taken in hand. A sheet of specimens of the various sorts of type to be used, and the purposes to which they are to be applied will also be found at the end of this chapter. The subsequent stages to be worked through to the completion of the map are as follows:—

Inking in rivers, streams, edges of cultivation, boundaries, &c.

" hill-shading, contouring, and broken ground.

Inking in with a ruling pen the roads to be shown.
Typing the names of provinces, districts, &c.
Finishing the headings, borders, foot-notes, references, &c.
Final examination.

3 The following instructions must be carefully attended to in each of the several stages. The ink to be used must be fresh, well rubbed up, free from grit, and perfectly black. Draftsmen who find their pens not working well, will occasionally dip the point into water. This habit is most objectionable, for although it answers the purpose of making the ink flow better, it makes it pale and unsuitable for photography. If the paper seems at all greasy a little oxgall may be added to the water with which the ink is rubbed up. When inking in small streams which, commencing with a single line, gradually increase in thickness until important enough to be shown by a double line, care should be taken that the change is not made too soon; and when it is made, that the relief line is not too thin, or there will be apparently a want of continuity in the stream, the effect produced by two fine lines being very much less than that by one thick one. The change from single to double lines should be effected where some affluent joins the main stream.

Precautions to be observed in the several stages of the map.

C O., No. 153, dated 6th October 1884.

D O No. 12, dated 25th May 1886.

Addendum D O No 12, dated 25th May 1886.

D. O. No. 11, dated 9th December 1885.

4. Particular attention is also to be paid to the correct rendering of the symbols for the different kinds of boundaries. As a guide to the draftsman cards have been lithographed, which give the correct lengths and sizes of the lines and dots; these may be obtained on indent from the Head Quarters office in Calcutta. In two of the patterns the distinction between two different kinds of boundaries merely lies in the size and thickness of the lines, the symbol used being the same; if care is not taken, and one is made a little too thin, or the other a little too thick confusion may easily be caused.

Boundaries.

C. O No. 174, dated 13th April 1885.

5. In inking in village sites, the lines marking their limit should be straight, when at least they have not been actually surveyed, but put in by tangents to their edges; this helps to distinguish village sites from tanks, the outlines of which are invariably curved.

No cross hatching of villages, nor water lines in tanks, should be drawn; as such lines, even when well drawn, are never reproduced satisfactorily by photo-zincography.

Village sites.

C O. No. 153, dated 6th October 1884.

C. O No. 153, dated 9th October 1884,

Symbols,

6. Symbols for bungalows, factories, a spear and shield (for police chaukies) are all to be omitted; in their stead will be printed the words Bungalow, Factory, Police Station &c., or suitable initials such as D. B, I. F. (indigo factory) which must be explained in the foot-note. The direction in which streams flow should be shown by an arrow pointing down stream. A list of symbols admissible in topographical maps on various scales will shortly be issued for the use of the Department.

C. O, No, 21, dated 24th January 1879,

Hill shading and contouring.

7. In inking up the hill shading or contouring, the chief point to remember is that the lines must be clean, and not too close to each other, as the tendency of photo-zincography is almost always to press out and blur more or less the strokes in the original drawing. If the country has been contoured either rigorously or approximately, it is all-important that the contours should be even and absolutely continuous. Contours at certain stated vertical intervals are generally measured in the field with greater care than the intermediate ones, which are inserted by eye only: these measured contours should be distinguished by being dotted, and their height above sea level should be given at convenient intervals. In drawing low broken ground it is a good plan to show it by small detached vertical touches, even though the general hill drawing is done on the horizontal system, as this latter does not readily lend itself to the portrayal of such ground.

C O. No, 59, dated 16th November 1880.

D, O, No, 4, dated 4th March 1885,

Roads.

8. In inking up the roads it is essential to use a drawing pen; no draftsman, however well his hand may be trained, can make a stroke as even and firm as may be obtained by the use of a drawing pen, especially if the road be a sufficiently important one to be shown by a double line. Some judgment is necessary in selecting the most suitable roads for insertion in the map. In plain country the field section is almost always overcrowded with them, and in drawing the fair map many of these must be omitted; and only such as have some continuity in passing on from one village to another, and connecting large places, should be retained. In hilly country it is rarely advisable to reject any, as the means of communication in such tracts form one of the most important items in a map.

C. O. No, 56, dated 23rd Sep, 80,

Typing.

9. Special rules for typing have been published for the use of the Survey Department, and are here abstracted for convenience of reference. Type of the various

descriptions now used in the Topographical Branch is obtained on indent from the Calcutta Office. On receipt of type a proof should be taken of each fount as it lies in block: it is well to remember that type when wetted holds together better than when it is dry. The number of the letters should be counted, as also of the spaces and quadrats. This latter information should be noted alongside the print of the fount. The knowledge that a proper list is kept, will go far to prevent petty theft by menials. Strong trays of equal dimensions, and of sufficient size to hold the largest fount in stock, should be constructed; they should contain space for not less than 70 divisions.

The type should be sorted into them carefully, each fount in a separate tray, and each letter into a separate division in that tray. A print of the letter, or whatever is contained in the division should be impressed distinctly on the upper side of the space. The capital alphabet, or upper case, should be kept separate from the lower case. There is an established proportion with respect to the number of each letter in any fount; it follows therefore that the space required for each letter in the tray is in the same proportion.

10. The cleaning of type that has been used is a very important point, and on it a good deal of the success of the typing depends. The impressions will never be clear and black, unless the old and dry ink is removed from the face of the type; nor will they be fine if the face and hair lines of the type are destroyed by rough usage during the process of cleaning. C. O. No 56, dated 23rd September 1880.

Cleaning type

After an impression has been taken, and before the type is removed from the holder, it can be cleaned by a soft, small camel's hair brush dipped in turpentine being lightly passed over it, and then dabbed gently with a ball of cotton wool. Type is thus always kept clean in the tray. The dabbing may be dispensed with if the type is not wanted till the turpentine has dried. It should be remembered that if it is necessary to wipe the fresh ink off the type when in the holder, a leather should be used and not a rag or cotton cloth: the hairs from a rag get into the ink, and spoil the impression by rendering it woolly. The typer should have by his side *away from the map* a little pot of turpentine; it is no trouble using it. If by neglect the old ink has got hardened on the letters, they should be boiled in a pot in a solution of soda (sajjí mattí), set up afterwards on a type board and polished with a very soft boot-brush, wetted in the same solution, and then dried with cotton wool. A hard brush, or old tooth-brush, should on no account be used. The

somewhat irksome duties of cleaning and sorting should never be neglected, but should form part of the daily routine.

C. O. No. 56, dated 23rd September 1880.

Ink for typing.

11. Typing ink should be new, and rubbed up daily: the old ink is easily cleaned off the slabs with a few drops of turpentine. The best ink for map-typing should be sticky between the roller and slab, and give off a crackling sound when rolled. Thin ink is useless: it will not dry and it smears. The best recipe for printing ink is as follows:—

| | | |
|---|---|---|
| Balsam of capivi | ... | 9 oz. |
| Lamp black | ... | 3 „ |
| Indigo and Prussian blue | | 1¼ „ |
| Indian red | ... | ¾ „ |
| Dry yellow turpentine soap | | 3 „ |

grind on a slab to an impalpable smoothness; this will make 1lb of the best ink. Ink ready prepared may be obtained either from the Calcutta or Dehra offices, or from any printing office.

A small quantity of the ink should be rolled on the slab, practice only will determine the exact amount required with each sort of type, but large type necessarily takes more ink than small, nor does it require such a stiff ink. A light even roll backwards and forwards with the roller on the face of the type, is all that is required to ink up a name. It is a good rule to set apart a table for typing in every survey office. A typer can be neat and clean if he chooses, but printing ink is apt to leave its mark, and when that mark is heavy it is a difficult business to erase it from the map.

Ditto.

Type-holders.

12. Type-holders are of two sorts, the ordinary vertical pressure holder, and the Gastrell pattern which has a lever. The one is used for ordinary names, and the other for headings, foot-notes &c.

The former is composed of two parts; the type-holder and the socket. A little practice will enable the typer to place the letters properly in the holder, but the following remarks deserve his careful attention. The type should always be placed as nearly as possible under the centre of pressure, *i.e.*, the handle of the holder. Great care should be taken to make the face of the type level; to attain which end it should be gently shaken in the holder, the back and side screws being moved alternately a little at a time, until the type is just held firmly: no excess of pressure should be used. When a small fount of

type is used, a piece of wood of suitable shape should be introduced into the holder, to fill up part of the type space, so as to save the flat spring from undue tension. Every endeavour should be made to get the face of the type level, and the whole in one straight line. A proof of every word should be taken on a separate piece of paper before the name is typed on the map, to see that the letters are evenly placed, and that none are defective.

Method of placing names.

13. The following very simple and effective method of placing a name on any particular spot is recommended in preference to any other. Under the mill-board on which the type-holder is mounted is placed a piece of tracing paper, projecting beyond the edge, so as to receive the name when the type-holder is pressed down; under this again is laid a piece of ordinary stiff paper* not projecting under the holder, but at the sides; so that by laying hold of it the whole apparatus, tracing paper, holder and all, can be lifted up and placed in any desired spot. An impression is first stamped on the tracing paper, and then the whole arrangement is moved bodily until the name on the tracing paper lies in its proper place over lines previously ruled on the map where the name is to be printed. The slip of tracing paper is then torn off, the type re-inked and the name stamped on the map. Village names should be printed to the east side of the sites, and parallel to the top and bottom edges of the map. Double curves for district names should be avoided.

Typing extended names of districts, &c.

14. If it is desired to print letters on a curve in an extended name, such as a province or district, a curve is laid down on the map, and along it at proper intervals a mark for each letter is made. At these marks normals to the curve are drawn. In the mill-board on which the type-holder is mounted a central narrow slit is cut and when the board is so adjusted that the normal drawn on the map coincides with this slit, it is obvious that the letter will stand in its proper relation to the curve.

C. O. No. 56, dated 23rd September 1880.

Pressure and pads used in typing.

15. The pressure and pad for each sort of type differ considerably; as a rule a small sized type requires a thinner pad, and less pressure, than type of a large size;

Ditto.

* Ordinary sand-paper with the rough surface upward, answers very well, as the grain prevents the tracing-paper, and the mill-board from slipping, when raised.

regard however must be paid to peculiarities of construction in the type itself. Practice alone will make perfect in regulating the pressure and pad required for each fount.

It is most objectionable to use a soft pad of many folds of blotting paper, or a sheet of india-rubber under the map when typing: the result of this is that the name is pressed deeply into the paper. It is no doubt easier to work with a soft pad, but it only requires a little extra care and trouble to get clear impressions on a hard pad, such as cardboard. Greater pressure is required, but the indentation made in the paper will be little or nothing, and the result will be sharper and better, more especially in the photo-zincographed copy.

C. O. No. 155, dated 6th October 1884.

Headings, margins &c.

16. The headings, titles, margins, &c., must conform to the specimens issued from the Head Quarters office in Calcutta, one is for reduction to one-half, and the other for reproduction to full scale. Foot-notes explaining anything that may be unintelligible to the public generally, should be carefully compiled and inserted. Those attached to the specimens are given merely as a guide, and must be altered if necessary A note as to the original scale of survey, and the method employed in reducing or reproducing the fair map must be inserted on all maps. A small table of areas must be given, showing the areas of states only, unless the survey is for some special purpose such as forest delineation, in which case it will become necessary to give other areas also: and lastly a linear scale must be inserted at the bottom of the sheet within the border, and an arrow showing the mean variation of the magnetic compass on the eastern meridian line, with the lettering *e.g.* "Variation 2½ degrees east" as the case may be, to the nearest quarter-degree.

C. O. No. 127, dated 28th January 1884.

C. O. No. 153, dated 6th October 1884.

Soiling the paper must be avoided.

17. The edges of the paper are not to be cut, but the full sheet must be sent in. The utmost care must be taken of the paper both to prevent dirt, and creases, whilst the map is in progress; it should be kept covered up in brown paper, only allowing the portion that is being worked on to be exposed; there is no excuse for dirt on a map that is prepared at leisure in office. A map should never be cleaned up with any form of india-rubber; it weakens the lines, and in many cases breaks them, and ruins the names which have been typed. If a map has not been carelessly dealt with, nor too black a pencil been used, there will be no necessity for cleaning it up at all,

if cleaning is indispensable it should be done with stale bread crumbs. If blue lines are used they should be of a light cobalt: dark blue lines are reproduced by photography.

18. Maps on scales larger than 1-inch = 1 mile for reproduction to the same scale, are occasionally improperly drawn very coarsely, and the names printed with large heavy type, as though they were meant for reduction. The individual lines by which the different topographical items are shown, should not be drawn coarsely because the map is on a large scale; the lines representing roads, villages, &c., should be as fine as is consistent with clear reproduction, no matter on what scale the map is drawn. Hachuring may perhaps, if based on eye-sketching, be somewhat bolder, but not inordinately so. Large scale plans of cities, cantonments, &c., are not here under consideration. C. O. No 153, dated 6th October 1884.

Coarse drawing on large scale maps to be avoided.

19. Photography is largely employed in the present day for reducing maps to smaller scales, to the almost entire exclusion of the old-fashioned method of pantagraphing, or reduction by similar squares. Ditto.

Drawing maps for reduction to smaller scales.

A map for reduction by photography should be so drawn that the reduced result shall be exactly like a map drawn direct on the reduced scale, but with the advantage of the extra sharpness obtained in the photo-zincographic copy, due to the process of reduction, whereby imperfections are also diminished.

Attempts have been made from time to time to draw maps in a slightly exaggerated style, so that they are fairly good when reproduced to full scale, and also when reduced to half scale. The results have never been successful, and both maps are bad. If an exaggerated map is required, it is better not to attempt to make it artistic by any half measures, but to sacrifice its appearance entirely to the requirements of the reduced copy. Orders are occasionally issued to a party to produce two sets of maps, both on the 2-inch scale, one for reproduction, and the other for reduction to the 1-inch scale. In this case the former should be drawn as finely, neatly, and with the same type as a map on the 1-inch scale; the general appearance of the map should not be coarser because it is on double the scale; the real difference lies in the fact that more minute detail, and a greater number of topographical items can be shown on the 2-inch than on the 1-inch scale, because there is four times the amount of paper to draw upon: but

this extra area of paper is not to be filled up by representing the same items in a coarser style of drawing. The other map for reduction will of course be in an exaggerated style, with such detail omitted as would cause confusion when reduced.

Drawing maps for reduction to smaller scales.

20. The simplest method of obtaining the reduction is to cover a photo-zincographed copy of the 2-inch map with bank-post paper carefully pasted over it, and passed through a press. The paste should be made of cornflour with a little alum dissolved in the water with which it is cooked, a very thin solution of gelatine in hot water also answers the purpose well. The paper is sufficiently transparent to allow of the details being seen through it, without being so distinct as to show in the subsequent photograph. The necessary details for the exaggerated map are drawn at once on the bank-post paper over the dimly seen map beneath, in the proper style for reduction; some judgment is necessary in selecting the details for omission, but this soon comes by practice. This is a very convenient way of re-drawing a map that may have been partly drawn, and left for some time incomplete for want of original surveys, the paper of which has become damaged.

C. O. No. 32, dated 13th June 1879.

Importance of examination of completed standard sheets.

21. When a standard map is completed in all details it has to undergo a thorough examination, a process upon which it is hardly possible to lay too much stress. It is obvious that however accurate and minute the original field sections may be, their value will be lessened exactly in proportion to the errors and omissions allowed to pass in the standard maps prepared from them. It is almost impossible to make a thorough examination of a map unless some definite system is adhered to; experience shows that the method here described is the most convenient, and the most searching. In the first place it should be noted that the examination must be conducted by an experienced officer, and not delegated to junior assistants who of all others have had the least experience in mapping. As this duty is of a monotonous and irksome description, there is always a temptation to give it to one of the junior hands.

Ditto. Method of examining maps.

22. The only really satisfactory method of examining the details of a copy with its original, is by superimposing the one on the other over a tracing-glass. This can be most conveniently done on

a horizontal table, out of which an aperture has been cut, the piece removed being replaced by thick glass; a heliotrope or other reflector placed beneath it, so as to reflect bright daylight on to its under surface, enables the examiner to see the details clearly.

It is evident that all the details of a map cannot be examined at a glance, and it is therefore necessary to adopt some plan by which a portion only may be examined at one time; this is most conveniently managed by dividing the subject into numbered rectilineal figures: these figures should be small; on the one-inch scale, five-minute squares will be found suitable. The portion of the fair map not under examination should be kept carefully covered, in order to avoid soiling; especial care must be taken that the paper is not creased or wrinkled by being pressed over the edges of the table, as is very likely to happen, if the table is smaller than the sheet under examination.

23. The examination of a map may be divided into two distinct branches, *viz.*, I. Accessory work, and II. Map detail. A form, P.73, has been prepared in which a number of different heads are arranged alphabetically in each of these two branches; and the use of this form greatly lessens the chance of any item passing unchecked. The examining officer with the form before him will check all the items specified therein, entering in Form P.72 any remarks as to errors, omissions, &c., that he deems fit. The map will be then returned to the draftsman, who carries out the orders entered in P.72 by the examining officer. The map is then complete, and ready for transmission to Calcutta or Dehra for publication; the examination report in Form P.72 accompanies it, as a sort of voucher to the care and minuteness with which the examination has been conducted. C. O No. 32, dated 13th June 1879. *Continued.*

24. By this means a strict scrutiny will be ensured, and in case of any errors being noticed in the Head-Quarters office, a similar report in P.72 is drawn up and sent with the standard sheet to the executive officer, who makes the necessary corrections, or specifies his reasons for not doing so. The Head-Quarters office will not necessarily re-examine all maps submitted to it in full detail, but certain heads will be selected in each case for re-examination, with reference to the failures of the same survey party in previous season's mapping. Ditto. *Continued.*

Issue and scrutiny of unpublished proofs.

25. When the manuscript map has thus been guarded against errors by all reasonable precautions, it is photo-zincographed, and one or more copies struck off and stamped "unpublished proof"; one of these will then be forwarded without delay, to the officer who is responsible for the original survey.

C. O. No. 116, dated 24th August 1883.

If the proof is forwarded during the recess season, the officer will pass it on to all the surveyors who were engaged on the original survey, and who happen to be present, for their examination of that portion of the map for which they are accountable, and for them to affix their respective signatures. The officer will himself also scrutinize the map generally, and will, after pointing out any errors or omissions, either in the body of the map, or in relation to the adjoining sheets, affix his own signature, and return the proof to the office of publication. This duty of final examination of a proof copy should be considered "urgent," so that all other work may give way to it, and the publication be in no way delayed. During the field season it will be sufficient for the responsible superintending officer only to examine, sign, and return the proof copy.

Ditto.

Issue of unpublished proofs to outside departments.

26. Previous to publication, stamped "unpublished proofs" may if necessary be issued to officials who may require them for *immediate use*;* the responsible officer should, as a rule, notify beforehand to the office of publication the names of officials to whom it is desirable to send them.

Before new editions of old maps are published, it will be advisable to send "unpublished proofs" to District Officers or Engineers who are employed in the locality,* with a request that any new works or details may be inserted by them, so that the reproduction may be brought up to date.

D. O No. 212, ated 28th ebruary 1870.

Procedure to be followed in colouring maps.

27. A map is rendered much clearer and better for general use when coloured, but as the process of photo-zincography precludes the use of colours they are added, if required, by hand after the publication of the maps. For this purpose three sets are furnished to the executive officer, which are then coloured in acoordance with the

* Confidential maps are not to be included in this rule, as special regulations exist with regard to them.

original field-sections; these latter not being intended for photo-zincography may be coloured to any extent. Of these three sets, one is retained in the office of the party for reference, and the other two forwarded to the office of publication. The items to be tinted are towns and villages, cultivation, forests, tanks, rivers, sand-banks, roads and boundaries. Towns are coloured carmine, villages burnt umber, cultivation raw sienna with *very* little indigo, forests gamboge and indigo, tanks and rivers cobalt, or Prussian blue, sand-banks and roads burnt sienna, and boundaries various colours, care being taken that a distinctive tint is used for each district, and that the same colour is always retained for the same district throughout the whole province or state.

28. Colouring, in connection with lines of shading of different styles, has been found admirably suited to the classification of forests and soils by those officers who are employed on this particular class of survey. The system is as follows:—A tracing of the field section is prepared by the surveyor, upon which the classification is noted by means of symbols, *pari passú* with the execution of the detail survey. Forest lands should be divided into five classes, *viz.*:— D. Memo. No. 18, dated 24th August 1889.

Method of classifying soils and forests by use of colour.

1. Forest where teak abounds without bamboo.
2. „ „ with „
3. Miscellaneous forest.
4. Grass lands.
5. Cultivation.

Soils should be divided into four classes, *viz.*:—

1. Very good and rich.
2. Medium.
3. Very dry.
4. Unproductive.

The class of soil is denoted by the *direction* of a system of lines drawn across the area, and the class of forest by the *colour* of the lines.

Thus for soils of the

1st class, the system of lines is vertical,
2nd „ „ horizontal,
3rd „ „ diagonal from N.W. to S.E.
4th „ „ „ N.E. to S.W.

These lines are drawn of the following colours for the different classes of forest:—

for 1st, red,
„ 2nd, blue,
„ 3rd, brown,
„ 4th, green,
„ 5th, yellow.

This is the system as adopted in the Central Provinces, but when used for other places would probably require some modifications, which would readily occur to any survey officer, and may be settled in consultation with the forest officers concerned. The surveyor keeps this trace up to date, and it should be examined in the field at the same time as the topography, and any difference of opinion about the correct classification should be then and there adjusted.

The extra trouble and cost entailed by this classification is insignificant, and has been estimated at about Rs. 7 per square mile: on the other hand the forest officers, to whom the trace is made over, gladly avail themselves of the information thus afforded them. These traces are not intended for publication, and may be drawn somewhat coarsely on tracing cloth: they are compiled into standard sheets of the same dimensions as those of the survey.

Distribution of maps after publication.

29. In order that the published maps of the Survey of India may be utilized to the greatest possible extent, the Map Record and Issue office in Calcutta should be informed by executive officers of the names and addresses of all officials to whom the maps are likely to be useful, with a view to a sufficient number of copies being despatched to them.

C. O No. 122, dated 18th December 1883.

Officers in charge of parties are therefore required to attach to each standard map sent in for publication, a slip giving the names and addresses of those persons to whom presentation copies of that particular map are to be sent. In this category should be included any native chiefs, or large proprietors who may have given aid to the survey party, and the chiefs of native states which may be included in the map. The names may also be given of any officials who may wish to have the map sent to them on service; but in conformity with Resolution No. 178 of the Government of India, Revenue and Agriculture Department, dated 23rd February 1886, the cost of these issues will be

D. O. No. 14, dated 17th August 1886.

debited to the department to which the officials belong. This rule does not apply to confidential maps for which separate orders exist.

Packing maps for transmission by post.

30. In despatching maps to Head-Quarters it is imperative that proper precautions be taken in packing. The safest plan is to enclose in a double tin cylindrical case a light wooden roller upon which the sheets have been wrapped. The tin case is then placed inside a light wooden box, which is covered with waxcloth and sealed. It is a rule admitting of no exception that original field sections, and standard maps of the same ground, are never to be trusted to the post together. A receipt for whichever of the two is despatched first should be obtained before the other one is forwarded. The loss or destruction of one of the two sets is comparatively of little consequence, but the loss of both entails re-survey. For the same reason original maps, field sections, and angle books, are only to be taken back into the field under very special and exceptional circumstances; and when so taken, either to or from the field, should be under the immediate care of the officer in charge of the party, or of some responsible European assistant, and never entrusted solely to khalásis or daftaris, and more especially originals and duplicates together. Original survey materials must be absolutely held and cared for on the strict responsibility of the officer in charge. A duplicate having once been made, or records having been once safely lodged in recess quarters, it is imperative to detach the copy from the original, so that both may not perish by the same accident.

D. O. (G.T.S.), dated 1st August 1850.

D. O. No. 259, dated 28th March 1871.

Completion of detail on original plane-table sections.

31. Before the original field sections are sent to Head-Quarters, there are certain details to be attended to in finishing them, and making them permanently intelligible and complete records for future reference.

C. O. No. 134, dated 11th March 1884.

The heights of all trigonometrical points must be inserted and a few selected clinometric (or barometric) heights of important points inaccessible to the triangulation. The adopted heights of all tower stations of the Great Trigonometrical Survey, are invariably referred to the summits of the towers; but this is apt to be misleading, especially in plains only slightly above the sea level. The height therefore should in such cases, as well as in those of temples, mosques, and other buildings, be expressed in the form of a fraction, whose numerator is

C. O. No. 85, dated 25th April 1882.

the height—above sea level—of the station, and the denominator that of the ground level as follows:—

Akra T.S.

$\frac{141}{98}$

which indicates that the ground level at the base of the Akra tower is 98 feet above sea level, and consequently the height of the tower is 43 feet.* This method of inserting heights is applicable to standard sheets as well as to the original field sections.

C. O. No. 134, dated 11th March 1884.

All village names, also those of rivers, tanks, mountains and other features must be inserted on the face of the map in their appropriate places. Symbols for temples, and other topographical items, according to the authorized list, must be drawn; also district and province names in appropriate lettering. The edges of each table must be examined with reference to the adjacent ones, and corrections, where necessary, be made in red ink by the officer in charge, and initialled by him.

Ditto.

32. The colouring of all items is to be carried out in accordance with the instructions given in para. 27 above, including also the triangulated stations, which must be coloured deep crimson to be more conspicuous to the eye. A border line must be drawn round the graticule similar to that in use on the standard sheets, the figures for the latitudes and longitudes being carefully hand-printed. This remark applies also to all names and numbering, which must invariably be inserted by hand throughout all field sections, and not by typing. The border line should include the whole section, even if only a portion has been surveyed. A section will always be considered as half of a final standard sheet.

Completion of detail on original plane-table sections.

C. O. No. 160, dated 1st November 1884.

D O. No. 2, dated 25th February 1885.

On the top of the sheet will be printed the words "Survey of India Department" with the name of the survey party in the centre, in bold block letters. In the right upper (or N.E.) corner, the number of the section must be given thus $\frac{\text{Sheet No. } 55}{\text{E.}}$. In the left upper (or N.W.) corner must be printed the names of states or districts included in the sheet; besides these the three following important items must be given, *viz.*, the season, the scale of survey, and the magnetic variation.

C. O. No. 134, dated 11th March 1884.

* It is the custom in the records of the Trigonometrical branch to symbolize the height above sea level of the top of the tower by the numerator of the fraction, and the actual height of the tower itself by the denominator.

Completion of detail on original plane-table section.

33. An area statement must be drawn up in some convenient place on the margin, showing the area of each district or state in the section, any overlap being noted as a separate item. These areas must always be checked by a comparison of their sum with the geographical areas included within the graticule lines. The areas may be taken off the sheets either by the planimeter, the talc square, or the acre comb. The first instrument is described at page 175, and the second at page 218, of the Manual of Surveying for India. The acre comb is merely a modification of the talc square, threads stretched across a brass frame being used instead of the engraved lines of a talc square. C. O No. 134, dated 11th March 1884.

The following information is also to be inserted at the foot of the map, *viz.*, the date of commencing and finishing the section, the total number of plane-table fixings, the average number of plane-table fixings per square mile, and the length in miles of test lines, which last should be drawn in red on the face of the map itself. Each sheet will also be signed by the surveyor, and countersigned by the officer in charge of the party. The remarks by the examining officer must be signed by him. Ditto.

*Continued.*

34. The paper is never to be detached from the cloth on which it has been originally mounted. The size of all the sheets should be equal; allowing for the removal of the dirty edge, which is always to be found round the board, it will be as nearly as possible 26 inches × 21 inches. As a further protection the edges must be bound with ribbon, as soon as possible after the sections are cut off the board. The ruling and printing on field sections should be done by surveyors, and assistants of all grades, who are not already skilled draftsmen, and it should be regarded by them as an invaluable practice by which their style may be rectified and improved. Sub-surveyors must be particularly cautioned against filling in the village names on a tracing kept for this purpose, under the pretence that their handwriting is not sufficiently good to write them direct on the map. The proper practice is to write the names in the village books with their distinguishing numbers, and also on the margin of the field section, affixing a corresponding number to the village site in the map. This is a necessary precaution, for otherwise the loss of the village book, or of the tracing, would necessitate a partial re-survey of the whole sheet in order to regain the lost names. Ditto. D. O. No. 19, dated 28th August 1889.

C. O. No. 27, dated 21st March 1879.

Atlas reductions. General remarks.

35. As the materials furnished by Topographical parties are destined, sooner or later, to be incorporated in the series known as the Atlas Sheets of India, it is desirable that some uniform system of effecting this should be adopted by all executive officers, in order to secure a proper division of labour between the field party and the engraving office at Calcutta.

A map, which has to be put into the hands of the engravers, is obviously liable to defects of different kinds when it is drawn in the Calcutta Office, and when it is drawn in the office of a field party. At Head-Quarters there is no such knowledge of the country as has been acquired by the surveyors; consequently in reducing from the scale of survey to that of the Atlas, there is a risk of omitting some useful details, and introducing others of no importance; in other words, there is a risk of failure in assigning to the results of the survey their correct relative value. On the other hand when the drawing is done in the office of the survey party, there is a risk that it may not be sufficiently in keeping with other parts of the Atlas. The following procedure is designed to meet these difficulties.

Third Addendum, dated 20th May 1889 to C. O. No. 27, dated 21st March 1879.

C. O. No. 27, dated 21st March 1879.

Method of preparing Atlas reductions in field parties.

36. Executive officers must prepare a reduction, to the Atlas scale, of each survey sheet; if the sheet exists on more than one scale, then that drawn on the nearest larger scale than that of the Atlas must be selected for this purpose: this must be done either from the sheet itself, as soon as possible after its completion, or *pari passu* with it from the field sections, so that it may be sent with the sheet to Head-Quarters at the end of the recess. This reduction is required to contain all the usual outlines of roads, rivers, tanks, and canals, and the names of towns, villages, rivers, &c., which are suitable for the Atlas, but no names of districts or native states: the crests, feet and general outlines of the hills are to be shewn firmly, in pencil, but without the full details of the shading, and merely as a help in placing the names appropriately on the map. After due examination in the Surveyor General's Office, and modification if necessary, to make it harmonize with the Atlas, this reduction will be put into the hands of the outline and name engravers, to be engraved on the several plates of the Atlas to which its details appertain. This skeleton map may be appropriately called the "Atlas Reduction".

The best method of preparing the Atlas Reduction is to obtain in the first instance from the Calcutta office, a print from a copper-plate showing the margins and graticule of the Atlas Sheet, on which any

details of the survey sheet will fall. Copper-plates have already been prepared on which the margins and graticules have been engraved for every sheet of the Atlas, the unsurveyed interiors being left blank to be filled in hereafter. Executive officers, in applying for copies from these plates, should specify the limits of the survey work which is ready to be engraved, in order that the corresponding prints may be supplied. These prints will be pulled "*dry*" in order that they may not be distorted in passing through the press.

A certain number of the triangulated, or traverse, stations, whose latitudes and longitudes have been computed—sufficient to serve as a basis for fitting in the interior details—must first be projected on the sheet. Afterwards the outlines must be inserted; and this should be done either by pantagraphic reductions from the originals, or by tracings from photographs, as may be most convenient in each instance. The accuracy of the pantagraphic reductions will be tested in the Calcutta office by comparison with photographs, which will be taken as soon as the maps are received from the survey parties.

Addendum dated 8th March 1881 and further Addendum dated 8th August 1883 to C. O. No. 27, dated 21st March 1879.

37. The amount of detail to be inserted is a matter of great importance; therefore when the pantagraphing or tracing has been completed, and the inking in is commenced, the further progress of the map should be carefully watched by the executive officer, who is responsible that nothing is inserted which should be omitted, and nothing put in which is better left out. Thus all *surface* watercourses, which are less than a mile in length, should be omitted, while all deep-cut watercourses with high perpendicular banks which can be shown, should be inserted, however short they may be. All ordinary roads leading directly from village to village may be omitted, as when numerous, they detract from the appearance of the map, and the existence of such roads may usually be assumed: on the other hand village roads which happen to be circuitous, on account of natural obstacles intervening on the direct lines, should be shown, as it is often of importance that the existence and general course of such roads should be known. All metalled roads and railways, and the principal canals must of course be inserted.

C. O. No. 27, dated 21st March 1879.

Amount of detail required in Atlas reductions.

All cities and towns must be given with some of their principal streets and squares, and as many villages as the scale will permit without overcrowding. The relative importance of the towns and villages should be indicated by the size of the letters used for printing their

names, as by sizes 4 to 6 for towns, and 7 to 9 for villages, in the engraved plate of specimens circulated with the order marginally noted: this plate must also be consulted for the proper symbols for stations, points, forests, swamps, boundaries, &c.

C. O. No. 27, dated 21st March 1879.

Style of drawing required.

38. Whenever an Atlas Reduction is under preparation, the executive officer should endeavour to assimilate it in style, as much as possible, to the best of the published sheets of the Indian Atlas, on which ground is delineated similar to the ground under delineation. These can always be supplied on application to the Calcutta office.

Ditto.

Suggestions for facilitating the projection of Atlas reduction.

39. Difficulty may be experienced in projecting stations, and points, on prints from the copper-plates, because the marginal lines are not minutely sub-divided. Executive officers should remember that the projections can be readily effected with aid of the cardboard scales of latitude and longitude for the Indian Atlas, which were printed in the Surveyor General's Office in 1876. These scales give the length of half a degree in longitude for each parallel of latitude, and are divided into 10″ both in latitude and longitude. Every print from a copper-plate contains at least one, and generally two parallels of latitude, and always two meridians at a distance of half a degree apart, which fix the lengths of half a degree in longitude for the limiting latitudes of the print. These lengths will usually differ slightly from the corresponding lengths on the cardboard scale because of the contraction and expansion of the print: when this happens the length on the scale should be sought which is identical with the actual length on the print, and adopted for reference, notwithstanding it may be the computed length for some other parallel. Similarly the latitude line to be adopted on the scale should be of the same length as the latitudinal half-degree on the print, as measured directly from the print when it has two parallels, or determined by the distance between any two parallels at 30 minutes apart, drawn in pencil across the print between the marginal divisions. There is therefore no need to sub-divide the lines on the print into minutes and seconds. It is to be remembered that all numerical longitudes depending on the elements of the Great Trigonometrical Survey, must be increased by 1′ 9″ to correspond with the origin of longitudes of the Indian Atlas, to which the meridian lines engraved on the copper-plates are referred; or the measurements may

Addendum dated 8th March 1881, and Third Addendum, dated 20th May 1889 to C. O. No. 27, dated 21st March 1879.

be taken from the blue ink meridians, which are sometimes drawn in the Surveyor General's Office to the right of the engraved meridians, and not from the engraved lines.

C. O. No. 27, dated 21st March 1879.

Rectangular co-ordinates the basis of Atlas sheets.

40. It is also advisable to remember that the margins of the Atlas sheets conform to a system of rectangular co-ordinates, which has been specially prescribed for them: whereas those of the Topographical sheets conform to the principal parallels and meridians, and those of the Revenue sheets to various independent systems; thus the Atlas sheets are on a different system of co-ordinates from all the others, so that in no case is a survey sheet an aliquot part of an Atlas Sheet, and the details of one of the former may fall into as many as four of the latter.

Addendum dated 8th March 1881 to C. O. No. 27, dated 21st March 1879.

Printing names.

41. Some difficulty will be experienced when printing the names on the Atlas Reduction—whether by hand or by type—in obtaining the exact sizes which are laid down in the sheet of specimens. Exact sizing need not therefore be attempted, but each word or numeral should have the proper scale-number written under it, in red ink, for the use of the engraver, who will be guided by the numeral instead of conforming to the actual size.

C. O. No. 27, dated 21st March 1879.

Brush shading to be used for hills.

42. When the details of the Atlas Reduction have been engraved on the copper, a print will be pulled from the plate, to serve as a skeleton on which the hills are to be inserted. The hills must be drawn by the method of brush shading, as it is found that scarcely even the most highly paid European engravers are able to etch hills on the copper from pen and ink originals. Wherever possible the brush shading must be done in the office of the survey party; but if done in the Head Quarters Office it must always be examined by the Executive officer, before it is put into the hands of the engravers.

Ditto.

Scale of the Atlas sheets.

43. It should be noted that the scale on which the Atlas is engraved is not exactly 4 miles to an inch; fuller information on this subject may be obtained by referring to the Auxiliary Tables, pages 51 *et seq.*

D. O No. 188, dated 10th August 1869.

Chart of triangulation.

44. Every Topographical party must draw up, season by season, a chart of triangulation. These charts should be limited to square degrees in dimensions, *i.e.*, 1° of latitude, by 1° of longitude, and are to be drawn on the ¼ inch scale*. They must be very carefully projected, and every station and point fixed by triangulation must be inserted thereon, and numerical data printed by hand or typed upon it so as to form a complete synopsis in a compact form of the basis on which the detail survey is built up. All principal triangulation of the G. T Survey is to be shown by thick lines. Secondary and Topographical triangulation by thin lines. Rays to intersected points should be dotted and not drawn throughout their whole length up to the stations from which they emanated; half an inch, or so much as is necessary to show clearly the station from which the ray proceeds, is sufficient. All stations and points should be marked by a small circle.

The numerical data of the principal G. T. triangulation should be as follows:—

Latitudes and Longitudes of stations to thousandths of a second.
Azimuths of sides " " "
Length of sides in miles to thousandths of a mile.
Log. feet of sides to 7 places.
Heights to nearest foot.

The numerical data for secondary, and Topographical triangulation should be as follows:—

Latitudes and Longitudes to hundredths of seconds.
Azimuths of sides " "
Length in miles to thousandths of a mile.
Log. feet of sides to 7 places.
Heights to nearest foot.

And the same for tertiary or intersected points, except that latitudes and longitudes need only be entered to the nearest second, and the length of sides and log. feet of sides omitted altogether.

It almost invariably happens that the plane-tablers report that some of the points projected on their boards are wrong, and that their positions do not agree with their true sites on the ground. This may be caused either by wrong plotting, or by failure of identification of the point from the two stations fixing it. If a point is fixed from

* The scale of the chart will vary according to the scale of survey, and the amount of data to be inserted on it. The above scale answers well for maps on the one-inch scale.

three or more stations, and the common sides agree, the error must be attributable to wrong plotting. All such points should, however, be examined on return to recess quarters, and those proved to be wrong should be corrected if possible, otherwise they should be expunged from the angle books, and field sections, and not allowed to appear on the chart of triangulation.

45. The chart should have scales of latitude and longitude drawn in convenient places outside the margin of the degree limits, in positions corresponding to their designation, and also two single-line scales of miles, one drawn parallel to the circles of latitude, and the other drawn parallel to one of the meridians. D. O. No. 346, dated 2nd February 1875.

*Continued.*

An index on the margin showing the number of sheets of standard maps falling within the degree is also necessary. The drawing of this chart must be in all respects suited to reproduction by photozincography. When it is published a sufficient number of copies will be supplied to the officer in charge of the party, who will affix one copy in each of the three volumes of the computations of the Degree Sheet, *viz.*, one in the General Report, a second in the Surveyor General's copy of original computations, and the third in the office copy of computations, so arranged as to fold in without being injured in binding the volumes.

46. All maps and charts relating to survey operations in any of the feudatory native states, or beyond the limits of British India are to be considered in the first instance as strictly confidential. They are not to be published, nor are copies to be supplied to any one without special permission from the Surveyor General, until their publication shall have been approved of by the Foreign Department. R. A. & C. letter No 195, dated 28th February 1876.

Confidential maps and reports.

The regulations about Trans-Frontier maps are most stringent. No maps of this kind are to be given to local civil officers or to Subordinate Governments or Administrations before submission to the Supreme Government. There is however no objection to rough results being forwarded to the Quarter Master General's Department for information, but not to local frontier officials. All such maps are stamped in the office of publication as "strictly confidential." C. O No. 152, dated 20th September 1884.

47. Most of the provinces of India are now provided with Index maps numbered on a regular system. The unit is an area measuring 15′ of latitude by 30′ of

Index maps.

longitude, this being the size of a standard sheet on the scale of 1 inch = 1 mile. The numbers appertaining to each of these units can however be made to apply to maps on larger or smaller scales than this by means of the following system :—

C. O. No. 106, dated 26th March 1883.

C. O. No. 110, dated 8th June 1883.

On the two-inch scale there will be of course four standard maps included in the unit. Supposing the sheet to be 14, then the four standard maps will be characterized as 14 N.E., 14 N.W., 14 S.E., and 14 S.W., respectively. On the four-inch scale there will be 16 standard maps in the unit. These will be distinguished as

$$14\frac{\text{N.W.}}{1} \quad 14\frac{\text{N.W.}}{2}$$

$$14\frac{\text{N.W.}}{3} \quad 14\frac{\text{N.W.}}{4}$$

and so on for the other quarters, the small figures always being placed in the order of west to east beginning at the north-west corner. For larger scales than the above, special index maps will have to be made, according to the particular requirements of the case. Within the limits of India proper, scales smaller than 1 inch = 1 mile are rarely used for Topographical surveys. If the scale be 1 inch = 2 miles, it is obvious that each standard sheet will embrace 4 of the above units, in which case all these four numbers should be inserted in the heading in the proper place, and enclosed within brackets.

Numbers of plane-table sections.

48. It is objectionable to assign a separate set of numbers to plane-table sections. The two sets of numbers referring to standard maps and plane-tables are confusing; those of the latter are only known to the members of the party itself; and the plane-table can be described equally well by the number of its standard sheet.

Ditto.

Numbers of square degrees.

49. In addition to the above sets of numbers, each square degree must have a number (generally in Roman figures) attached to it. This arrangement is for the purpose of designating the particular square degree embraced in the triangulation charts, the details of which are contained in the General Report volumes, each of which bears the same Roman numbers as the corresponding chart of triangulation. This set of numbers is not of general application, but refers only to the operations of that particular party.

Ditto.

## CHAPTER III.

# Miscellaneous Subjects.

### SECTION I.—PREPARATION OF THE ANNUAL REPORT, &C.

1. A detailed account of the annual operations of each survey party must be submitted to the Deputy Surveyor General not later than the 30th September in each year. This account is called the "Annual", or "Narrative Report", and must be drawn up in strict conformity with the following rules:—It must be prepared on foolscap paper with quarter margin, (not in duplicate) having marginal notes inserted explaining the subject of each paragraph. A covering letter, directing attention to any points requiring an early answer, should accompany the report. The writing must be clear and good, and names especially must be written in round Roman hand in contradistinction to ordinary running hand. Foreign words should be used very sparingly, if at all; and the style should not be egotistical. Nothing should be admitted which is not thoroughly reliable and of permanent value; all instructions and orders should be distinctly alluded to, and professional discussion of the merits of the work should be full and precise.

Annual or narrative report.

D. O. No. 346, dated 2nd February 1875. C. O No. 50, dated 1st April 1879. D. O. No 137, dated 9th February 1888.

2. In drawing up this report the following heads have to be considered in the order quoted:—

Details of report.

D. O No. 346, dated and February 1875,

1. Introduction.
2. Strength of party on taking the field, and changes during the year.
3. General plan of detail survey operations.
4. Date of leaving recess-quarters for the field, route of march, and orders to assistants concerning the commencement of their work.
5. Triangulation completed, and remarks on the same including the instruments used.
6. Remarks on the country triangulated, specifying the locality.
7. „ „ „ plane-tabled „ „ „ and area completed.

8. Details of the work done by each member of the party, from the officer in charge down to the sub-surveyors, both in the field and in recess. This head must include operations of all kinds, triangulation, plane-tabling, traversing, checking plane-tables, &c. The length of test-line in each piece of work must be given, time devoted to the testing of each, and by whom tested. The services and capabilities of every assistant and sub-surveyor must also be reported upon.

9. Notes on forts, towns, cities, hills and passes; on roads, rivers, canals, irrigation; on the manners, customs and language of the inhabitants; on rainfall, cultivation, manufactures, &c.

10. Duration and close of field season, and health of party.

11. Recess duties; computations, maps, charts, &c., remarked on in separate paragraphs, and connection with the principal G. T. triangulation.

12. General remarks on work completed.

C. O. No. 151, dated 1st September 1884,

13. Programme for the ensuing season.

D. O. No. 346, dated 2nd February 1875.

Index map and tabular statements to accompany report.

3. The report must be accompanied by an index map showing the following items by strong washes of suitable colours:—

Area completed previous to season under report.
„ surveyed in detail during „ „ „
„ proposed to be surveyed during next field season.
„ triangulated during season under report.
„ proposed to be triangulated during next field season and also

by the following tabular statements:—

O. 56. Detail of triangulation.
O. 57. „ of topography.
O. 58. „ of traversing.

C. O. No. 30, dated 1st April 1879.

Precis of annual report.

4. All officers in charge of survey parties must send in with the annual report a brief precis of it, framed in such a manner as to convey sufficient information on the subject and nature of the operations to a Secretary to Government, or other individual not conversant with the technicalities of survey. It should not be a mere abbreviation of each paragraph of the full report, nor should it be written in the first person; but should

be a concise report in itself, and ready for publication as it stands. When Indian terms are used a translation of them should be given. The brief accounts of the work of each party as printed in the Annual reports of the Department, Part II, furnish a good guide to what is required in a precis.

Reports due from subordinates.

5. All subordinate officers of the party are required to submit to the officer in charge monthly (or oftener if required) during the field season, a diary in Form O.45 and progress report in Form O.47.

Confidential reports.

6. All reports on survey operations or on any other kindred subjects, beyond the limits of British India, and of the feudatory Native states, are to be considered as subject to the same restrictions with regard to publication, as maps and charts, (*vide* Chapter II, Section II, para. 46). C. O. No. 150, dated 5th September 1884. C. O. No. 10, dated 23rd June 1885.

Visits to other survey offices in the same station.

7. Officers of the senior division must consider it part of their duty during recess to visit the offices of any other survey parties that may be recessing in the same station. It frequently happens that the procedure of different parties varies in some particulars, and mutual visits between the officers concerned tends to utilize to the utmost their varied experiences. C. O. No. 109, dated 23rd May 1883.

Visits to Head-Quarters offices.

8. Officers of both divisions visiting the presidency should, unless incapacitated by ill-health, be officially conducted through the offices of the Survey of India; and be made acquainted as far as possible with the procedure of the Drawing, Engraving, Mathematical Instrument, Photographic and Lithographic offices. Advantage should be taken by officers passing through Dehra of the opportunity to pay an official visit to the offices of the Trigonometrical Branch, after having obtained permission from the Deputy Surveyor General. Ditto.

Arrivals to be reported to senior survey officer.

9. Officers and surveyors of all grades will in future not only report in person their arrival at the Head-Quarters of the Survey of India at Calcutta and Dehra, but at all stations where an office of the Survey of India is established, they will visit that office, and intimate their addresses to the officer in charge. In the case of a station where there are several parties quartered together, the visit will be made to the senior officer present. C. O No. 126, dated 21st January 1884.

## SECTION II.—MANAGEMENT OF THE HEALTH OF A PARTY.*

General remarks.

1. Although in general the occupation of a surveyor may be reckoned more healthy than any other mode of life in India, on account of the fresh air, constant exercise, and interesting nature of the employment, still there are some tracts of country in which topographical survey parties are exposed to considerable risk from jungle fever and other diseases which prevail with greater or less virulence for several months in the year.

2. Such tracts cannot be avoided; for detailed surveys must be made for the civil, military and political purposes of Government, as well as for those projects of amelioration and improvement which can only be founded on accurate surveys.

3. As these parts of the country must, therefore, be surveyed like the rest, it becomes an important matter to consider the best sanitary arrangements for the protection of survey parties, from jungle fever in the first instance; and secondly, the proper treatment and line of conduct to be pursued in the event of the disease breaking out as an epidemic in camps.

4. That it is practicable, by judicious sanitary arrangements, to carry on operations with comparative safety for several months in such tracts, has been proved by the experience of the Survey Department in all parts of India; while it has also been demonstrated that, by proper medical treatment, disaster may be prevented, and the establishment restored to efficiency after being attacked by jungle fever.

5. Although it may, at first, appear to be beyond the province of a non-medical person to enter on a subject of this nature, still surveyors are of necessity thrown upon their own resources, and compelled to qualify themselves, as well as they can, to perform this work of humanity, in addition to their own all-absorbing duties. Fortunately, the treatment of jungle fever, if taken in hand on the first appearance of premonitory symptoms, and the patient be not unnecessarily exposed

* This section is reprinted from an Extract from Remarks on the Sanitary arrangements of Survey parties in the jungly tracts of India, by Colonel Sir Andrew Scott Waugh, Surveyor General of India, Dehra Dún, October 1861.

to aggravating circumstances, is sufficiently simple to be learned by any person of common sagacity, and will prove successful in nineteen cases out of twenty; though, if once the disease be allowed to gain head, it will require the utmost skill and refinement of the physician's science to reduce it. Whatever rules are here given have been derived, in the first instance, from the advice of medical friends; they have been tested by experience, and are believed to be consistent with modern practice, as far as they go. When once a moderate degree of skill is acquired by experience, combined with the advice which medical officers are always willing to afford, it will be found that a degree of confidence will be inspired among all parties in camp,—a feeling indispensable to success in all arduous undertakings.

6. Although several cases of failure have occurred in the progress of the Indian surveys, owing to the disastrous effects of jungle fever, these have generally happened from the want of experience; and instances are numerous where the work has been carried out with success, notwithstanding the prevalence of this disease. There are even instances where one portion of a party has escaped on the same tract in which another portion has suffered, merely owing to the difference of habit and treatment.

Long fasts to be avoided.

7. The benefit of breakfasting the whole party before starting has been proved by the practice of a number of officers; and to this, as well as to the superior stamina derived from good living, may be attributed the circumstance, that Mussalmans are less subject to the influence of miasma than Hindus, who cannot conveniently cook oftener than once a day. Nevertheless, the latter class of people should be induced to eat parched grain or something similar to break their fast, or be compelled to cook a regular meal in the early morning, if employed in very insalubrious places.

8. Early in the season, when marching to the field of survey, and afterwards on returning to quarters, when the weather is very hot, it is usual to move at night, to save the men from exposure to sun. It is impossible so far to break up established habits as to breakfast in the middle of the night; but it is usual for officers to take a cup of coffee and a biscuit; and as a further precaution, if likely to be detained out long, it is a good plan to fill the pockets with biscuits, ginger-

bread-nuts, or something of that sort, and carry a bottle of cold tea or cold weak coffee without milk.*

9. In the survey season, surveyors are liable to be out all day, from morning till night. In such circumstances it is desirable to be accompanied with a basket containing sandwiches, &c.; for the great object is to avoid having to labour under a feeling of exhaustion arising from mere want of food—a state in which the human frame is peculiarly susceptible to malarious influences. For this reason the men should have a lunch of parched grain and sugar, when out at work through the whole day.

Predisposing causes in case of native establishment.

10. Now, it may be remarked that most officers take these precautions for themselves: they also sleep under canvas, protected from the dew, and upon beds raised above the exhalations of the ground. But the experience of the Department shows that a large proportion of the native establishment and servants may be laid up with fever and brought to the verge of death, without the officer in charge or assistants being affected in the smallest degree. This will always be the case, unless the Europeans are of weakly constitution, peculiarly susceptible to fever, or neglectful of their comforts.

Proper protection at night.

11. It is difficult in the case of Hindus to get them to cook their meals at proper times, but as far as possible it should be done; and all surveyors who are careful of their men are sedulous to protect them from dew at night, and to furnish them with straw to sleep on. The use of camel carriage in Upper India renders it easy to carry charpoys for some of the upper servants; and when men are detached to show signals from hill stations, they are always directed to hut themselves, which can easily be effected in the jungles at the expense of two or three rupees. In the case of a party recently employed in malarious tracts in the Central Provinces, the executive officer has furnished his men with tea, blankets and filters. The effects have been so to increase their efficiency that the cost of these comforts has been abundantly repaid by increased outturn of work.

* Make coffee as usual and pour into a bottle till half full, fill up with hot water and add sugar according to taste: a man can work all day on this beverage.

Quinine as a preventive.

12. In addition to the ordinary precautions above directed, it is usual in the case of persons very susceptible of fever to fortify themselves by taking quinine while they are employed in unhealthy localities; and this certainly has a good preventive effect.

Importance of open camping grounds and good water.

13. In order to avoid the particular spots which are unhealthy, all due enquiry should be made of the indigenous inhabitants, with whom relations of amity should be maintained. The cleared and inhabited parts should be preferred for camping on, or high open spots, and the vicinity of rivers avoided, as well as closely wooded places, where there is no circulation of air or sunshine on the ground. Every enquiry should also be made for good drinking water; when it is likely to be scarce, it should always be carried on from the last stage, in order that time may be given to find out the best water at the new encampment: many persons use boiled water—a precaution which even the native inhabitants practise in some parts. In some parts of India well water is considered the most wholesome, while that from streams is reckoned deleterious. In other places well water is considered to occasion fluxes, but this is only where the soil is impregnated with saline substances. As a general rule, in all tracts much covered with vegetation, river water is dangerous, and resort should be had to wells. But it must be recollected that the water in old wells not in daily use, and filled with rubbish, is always stagnant, putrid, and more dangerous than any other water.

Hospital assistants.

14. Survey parties are usually attended by hospital assistants, who compound the medicines and act according to the orders of the officer in charge. These men are very useful in attendance on the sick, in general arrangement and hospital duties, and some are pretty skilful in the use of medicines; but, as a general rule, they are wanting in a strong mind to fall back on for advice in times of difficulty and danger, being either disposed to act with timidity or rashness. Be this as it may, the attendance of the officer on the sick prevents neglect, and cheers the poor men in their misfortunes. It sometimes happens, however, that the hospital assistant requires to be left at some distance, while observations are being taken on hill tops, moreover it usually happens that some of the subordinates being detached are unable to avail themselves of the

hospital assistant's services. Under such conditions in order to avoid the weighing and mixing of medicines which is not a very pleasant business at any time, and particularly irksome to a man fagged by a hard day's survey work, it is a good plan to furnish each person with a set of medicines prepared and weighed out beforehand, whereby all trouble will be saved.

Folly of neglecting reasonable precautions.

15. It may be said that the sedulous attention here recommended to ensure the comfort of every individual in camp would substitute, for the ancient hardy habits of the Indian surveyors, a sybaritic regard for luxury, inconsistent with the nature of the duties. It may look much more manly to be able to brave malaria on an empty stomach: but what is the use of hardy habits and contempt for comfort if no work is done? It is a very good thing to be able to brave an Indian sun with impunity; but it will be found that an umbrella will enable any man to accomplish more survey work than he could without that protection. The quantity of work is the only criterion of good habit and arrangement, and all other experience shows that, unless a party take the field well equipped with tents and other comforts, health is endangered, and the interests of Government are sacrificed.

Healthiness of camp life.

16. The number of diseases to which a party under canvas are exposed are comparatively few, provided the health of the persons composing the party was good at starting, that the coolies &c., are well provided with warm blankets during the cold season, and that every care is taken to keep the camp clean, dry, and within easy reach of a supply of good drinking water.

17. Most of the diseases to which survey parties are liable are treated of at considerable length in Moore's Family Medicine for India, a book which all European members of a Survey party should carry with them. The price of this work is Rs. 3 to all government officials receiving less than Rs. 500 per mensem, and Rs. 4 to all others, and to the public at large. A certificate declaring that the book is to be purchased only for the personal use of the officer is necessary for the lower rate. It may be convenient however to give here a brief description of the symptoms and treatment of the commoner forms of sickness prevalent in survey camps.

Fever.

18. Malarious fevers are beyond question the diseases which most tend to interfere with the progress of Survey parties in India; and a clear conception as to how they should be treated in a general way in cases of emergency is of very great value to every person liable to exposure to malarial influences. The fevers are referred to under various designations in this country, such as *Fever and Ague, Terai fever, Marsh fever, Bengal fever, Jungle fever, &c.* The affections commonly referred to by these names correspond to what medical men describe as *Intermittent* and *Remittent* forms of malarious fevers. By intermittent fever is meant that form of fever which, whilst recurring daily, on alternate days, or every third day, leaves the patient fever-free in the intervals; there is an *intermission* of feverish symptoms—in the first case of one day, in the second of two, and in the last of three, more or less, clear days. In the case of remittent fever, however, the feverishness does not completely disappear between paroxysms, there is simply a diminution—a *remission* of the attack. It is the severer attacks of this latter form of malarious disease that is usually meant when the terms *jungle* and *terai* fever are used, whilst the former is commonly referred to as *ague*.

It is, however, frequently difficult, even for the experienced physician, to decide definitely whether a person is suffering from the intermittent or the remittent form of the malady, as the symptoms often 'shade off' one into another—the fever being intermittent for a few days, then remittent, and again, perhaps, intermittent.

Fortunately the general line of treatment to be adopted is the same in both forms, and it will probably be found that when working in some malarious localities, the two forms of the disease may prevail simultaneously.

Prophylactic measures.

19. When it has been decided to visit a locality known to be productive of fever, it should be laid down as a general rule that every member of the party should receive small doses of some cinchona preparation during a few days previously, and twice daily during the stay in the locality. Two to three grains of quinine should be taken morning and evening, or, what is equally efficacious and very much cheaper, the same quantity of the *Cinchona febrifuge*, prepared at the Government cinchona plantation. The expense of a prophylactic measure of this kind would be very trifling, especially if the *febrifuge* be resorted to.

Intermittent fever.

20. An attack of ague consists of three more or less distinctly marked stages: a *cold* stage, often not well marked, but it may be severe and last from one to four hours; a *hot* stage, which may last from three to six hours—seldom more than twelve; and a *sweating* stage, which terminates in a couple of hours, and is followed by complete relief. The average duration of the attack is from five to six hours.

Treatment.

21. When the slightest symptoms exist of an impending attack of fever, the condition of the bowels should be attended to, and if any tendency to constipation exist, a mild purgative may be administered—a small dose of castor oil being the safest. Should it be considered advisable to administer a purgative, wait for an hour after its administration, and then give 10 to 15 grains of quinine [or an equivalent dose of the cinchona febrifuge], and repeat the dose in about six hours. Early and vigorous treatment of this kind, if not always successful in warding off the attack altogether, tends greatly to diminish its severity.

Should the symptoms continue, and shivering set in, marking the advent of the *cold* stage, the patient should be well wrapped in blankets; hot bottles, or hot bricks wrapped in flannel, should be applied to the feet, and warm tea, toast and water, or some such simple fluid given him to drink. Should constipation have existed which the castor oil had not relieved, a mild purgative may again be administered during this stage. Say a drachm of compound jalap powder in a wine-glassful of water, or a podophyllin pill.

Should, however, there be only slight constipation, await the advent of the *hot* stage, and administer two teaspoonfuls of granular citrate of magnesia or a laxative dose of pyretic saline in half a tumbler of water. Half a teaspoonful of this granular preparation, added, as required, to a little sweetened water, and administered every hour or so, will form a pleasant effervescing febrifuge. If, however, the bowels are relaxed, it will be better to keep to cold tea or toast and water, according to the patient's inclination. The bed clothes may be gradually lessened as the hot stage progresses, and attempts should be made to relieve headache by applying wet cloths to the head.

As soon as the *sweating* stage sets in, 10 grains of quinine [or an equivalent quantity of the Cinchona febrifuge] should be given every eight hours or so during the *intermission*. The quinine (or the cinchona febrifuge) may either be taken in powder, or dissolved by means of half

a teaspoonful of the juice of a lime, and taken in a wine-glassful of water. Care should be taken to avoid a chill during the hot and sweating stages. Should diarrhœa be present, a dose of chlorodyne may be administered during the intermission, and each dose of quinine combined with 3 grains of Dover's powder.

Treatment of Remittent, or jungle fever.

22. The general rules thus laid down for the treatment of intermittent fever are equally applicable to the treatment of the generally more serious form of malarious disease called jungle fever. The premonitory symptoms should be treated on precisely similar principles, with the addition that it is more advisable to abstain from partaking solid food shortly before an attack is anticipated, as vomiting, which is a prominent symptom here, is apt to be more aggravated than when the stomach is empty.

Should the mild purgative and preliminary doses of quinine not have sufficed to ward off an attack, the cold stage will be ushered in by more or less distinctly marked shivers; but it will be found that, as a rule, this stage is less marked here than in an ordinary attack of ague; the succeeding or hot stage, however, is more prolonged, and generally more severe. The temperature runs high, the pulse is very quick, often bilious vomiting of a very obstinate character occurs; the tongue is furred, and sometimes jaundice sets in. The patient is very restless, and his remarks often incoherent.

This stage may last from six to eight hours or longer, and, instead of terminating in severe sweating, followed by complete relief from all painful sensations, as in intermittent fever, there is only a subsidence in the severity of the symptoms—a *remission*, not a cessation, of the fever. The duration of the paroxysm is uncertain—may last from 6 to 24 hours, and an attack may recur daily for a week, 10 days, or even longer.

When the cold stage has passed away, and the pulse becomes full and the face flushed, administer frequent small doses of the granular citrate of magnesia as above directed, and apply cold to the head: avoid stimulants of all kinds, but attempts should be constantly made to get the patient to partake of beef tea, Liebig's extractum carnis, and such like nutritious food in a liquid form.

If the patient becomes delirious, the lower part of the back of the head should be shaved, and a blister (about 2 inches × 3 inches) raised, by means of blistering fluid, across the nape of the neck. If this be of no avail, and the pulse continues full and bounding, and the patient

be a strong man, four to six leeches may be applied to the temples—the bleeding being arrested when the leeches have dropped off. It is advisable to defer giving quinine until the remission sets in. This will be known by the diminution in the temperature, and the appearance of a gentle perspiration, together with, probably, the disappearance of the head symptoms. Five grains of quinine may now be given every three hours in the form of a mixture, or dissolved in the juice of a lime with water. Nourishing food should be given, with a very little stimulant, if desired. Should the patient suffer from diarrhœa also, the 5 grain quinine doses given during the remission may be combined with 3 grains of Dover's powder. If the head symptoms have been severe, it will perhaps be advisable to keep to quinine, but otherwise an equivalent dose of the cinchona febrifuge may be safely substituted for it.

If the attack has been severe, have the patient removed, if practicable, as quietly and as expeditiously as possible, to the nearest station where medical aid can be procured. This is especially desirable, if the disease has recurred two or three times without any appreciable diminution in the aggravation of the successive attacks.

Treatment of diarrhœa and dysentery.

23. Diarrhœa and dysentery sometimes appear suddenly in a camp, and in aggravated forms, and require prompt attention, especially as the former is very apt to pass into the latter in malarious districts.

The first precaution to be taken on the advent of diarrhœa is abstinence from solid food; nutritious food in a liquid, or semi-solid form should be substituted, and cold drinks should be avoided. Should the diarrhœa have been immediately preceded by constipation, a small dose of castor oil should be taken, and possibly after this has acted, the bowels may return to their ordinary condition.

If, however, the diarrhœa has not been preceded by constipation, 30 drops of chlorodyne may be taken in half a wine-glassful of luke-warm water. Should there be pain in the bowels, warm water fomentations should be applied to the stomach, and a flannel belt tightly drawn round. Three or four hours after taking the chlorodyne, 5 grains of quinine, or 5 grains of the cinchona febrifuge should be taken in combination with 5 grains of Dover's powder, and the patient sent to bed. It is probable that after prompt action of this kind, the patient may find himself perfectly well by the next morning: if not, let the chlorodyne be repeated, followed by the quinine and Dover's powder, twice daily, for a day or two, or until perfect recovery.

Should the diarrhœa pass on to dysentery, which may be inferred if irregular attacks of griping pain in the abdomen persist with increasing tendency to strain at stool, the condition of the stools themselves should be carefully noted, and if traces of blood or fleshy shreds be observed, it is absolutely necessary that complete rest should be enjoined. The patient should be given a grain of opium, or 30 drops of chlorodyne in a little water, to be followed in about quarter of an hour by 20 grains of ipecacuanha powder in half a wine-glassful of water, or the powder may be given as a bolus. This medicine will probably be succeeded by nausea, but every attempt should be made to keep it down. This is best done by the patient remaining on his back; indeed throughout the attack the patient should be made to lie down. Repeat the ipecacuanha powder in about three hours, and continue the dose twice a day for two or three days, or until the disease stops. Hot bran or linseed meal poultices should be applied constantly to the stomach; and should there be severe pain, apply a turpentine stupe (made by pouring about a tablespoonful of turpentine on a piece of flannel wrung out of hot water) over the painful part.

If the patient does not recover in about a week after a fair trial of this treatment, he should be carried to the nearest station where medical aid may be procured.

Cholera.

24. When cholera breaks out in a camp, the first step to be taken is, to shift the tents to some considerable distance; and if this does not suffice, shift again, across a river if practicable: of course the greatest possible attention should be paid to the sanitary state of the camp, and especial care taken during periods of this kind in particular to avoid unwholesome food and impure water.

Treatment of cholera.

25. Unfortunately no very certain remedy is known for this disease, but much may be done by early treatment. The premonitory diarrhœa, if present, should be treated with 30 drops of chlorodyne every three or four hours, and complete rest enjoined. Should, however, the stools become watery in appearance and mixed with bran-like flocculi, the pulse become small and thready, the skin blue and pinched, and the voice husky, 10 drops of the '*Cholera drops*,' supplied by the Medical Stores Department, should be given every half an hour in a tablespoonful of water. Or, if this medicine be not at hand,

15 drops of sal volatile should be given instead, in half a wine-glassful of water.

When severe cramps of the limbs or of the muscles of the chest come on, the painful parts should be sedulously rubbed with a mixture of ginger (or mustard) powder and linseed meal, easily obtainable in any bazaar, and cold drinks (soda water and the like) given when desired to quench the great thirst, from which the patient will in all probability suffer.

As soon as reaction sets in, the pulse regain its strength, and the unexposed parts of the body become warmer to the applied hand, the stimulating medicine (whether 'cholera drops' or ammonia) should be discontinued. Attempts should be made to get the patient to swallow a little beef tea, Liebig's extractum carnis, or such other nutritious food as may be available of an allied character. Occasionally, small effervescing draughts, made by adding half a teaspoonful of citrate of magnesia to a little sweetened water may be given. Should the urinary functions not have become restored towards the end of the second day, the loins should be well fomented with warm water, followed by a turpentine stupe applied over the kidneys, with a linseed or bran poultice over the bladder. Should indications of stupor be observed, and the tongue become dry, the back of the head should be shaved, and the nape of the neck painted two or three times with blistering fluid. As a rule, when the urinary secretion becomes re-established, convalescence is rapid.

Sun-stroke.

26. The Europeans of a party are more liable to suffer from sun-stroke than the natives, and it not uncommonly happens that when one attack has occurred, it is followed during the next few days by others. It is therefore especially necessary that the tents should be pitched in shaded positions, and that great care should be taken to avoid unnecessary exposure to the sun's influence for some days after a case of this kind has occurred.

No very clear description can be given of the symptoms which precede an attack, and very frequently none whatever are observed: a person may become suddenly faint, and fall without having given any previous intimation of his state.

Treatment of sun-stroke.

27. The *treatment* for such a case is, to lay the patient on his back in the shade, have his limbs well rubbed, and a dose of sal volatile (40 drops) in water

administered, or, if ammonia be not at hand, a little brandy and water may be substituted.

Should, however, the face get flushed, the pulse full, and the heat of the body to the applied hand very great, with stertorous respiration, the *bhisties* should be called and directed to pour a continuous stream of cold water from their *mussucks* upon the patient's head for several minutes, the head being, meanwhile, kept well elevated. Should this procedure not prove successful in improving the patient's condition, the back of his head should be shaved, and blistering fluid painted over the part, so as to raise a blister about the size of a man's hand.

Two drachms of compound jalap powder should be administered in a wine-glassful of water, followed in the course of half an hour by 20 grains of quinine, in solution if possible. Attempts should also be made to clear the bowels by means of warm water enemata, if practicable. During recovery absolute rest must be insisted on, nourishing food should be given, with only a minimum of stimulants, and the patient not allowed to resume work in the sun for some weeks.

Supply of medicines for detached parties.

28. A short list is appended of the medicines which would be found useful in cases of emergeney of the kind referred to above. Only the simpler kind of remedies have been mentioned, as it would be useless to do more than suggest the general line of treatment which meets with the approval of the majority of the profession. Were more than this done, it would tend to confuse non-professional persons, and an elaborate list of remedies would imply a great addition to the weight to be carried.

A LIST OF MEDICINES, &C., WHICH, IT IS SUGGESTED, SHOULD BE TAKEN BY SMALL DETACHED SURVEY PARTIES OF ABOUT 25 MEN.

½ oz. *Sulphate of Quinine.*

2 oz. '*Cinchona Febrifuge*' or 'Mixed Cinchona Alkaloids.'

1 oz. *Chlorodyne.*

2 oz. '*Cholera Drops,*' as issued by Medical Stores Department. Ol. Anisi, Ol. Cajeput, Ol. Juniper, each ½ ounce, Æther ½ ounce; Liquor Acid. Halleri ½ ounce; Tinct. Cinnam. 2 ounces; mix. Useful as a stimulant in the cold stage of cholera, and in other cases where a stimulant is desirable: 10 to 15 drops in water for a dose.

2 oz. *Sal Volatile* (Sp. Ammon. Aromat).

8 oz. Granular *Citrate of Magnesia.*

8 oz. *Epsom Salts.*

8 oz. *Castor Oil.*

2 oz. *Compound Jalap Powder:* a brisk purgative: dose 1 or 2 drachms.

1 oz. *Dover's Powder.*

25 One-grain opium pills [in a well-corked phial].

50 *Podophyllin pills* [Recipe, Podophylli Resinæ gr. ¼; Extr. Hyoscyam. gr. 1; Pil. Colocynth Co. gr. 3. Make a pill]. Preserve in a well-corked phial.

50 Two-and-a-half grain *Quinine pills.* In a well-corked phial.

25 *Gallic acid* (three grains) and *opium* (half a grain) *pills.* In a well-corked phial. Useful in mild cases of diarrhœa: one or two for a dose.

1 oz. *Ipecacuanha Powder.* For treatment of dysentery.

1 oz. *Blistering Fluid.* [In order to produce a blister, paint the part three or four times with a feather].

2 oz. *Solution of Acetate of Lead* [Liq. Plumbi Subacetas]. For making Goulard's Lotion, add about a tablespoonful to a pint of water. A useful application to sprains and to indolent sores.

1 oz. *Tincture of Steel.* Useful for stopping hæmorrhage. Dip a cotton rag into the solution, press it into the wound, and apply a bandage.

1 oz. *Tincture of Iodine.* Useful in reducing swollen glands (buboes) in the armpit, groin, &c. Paint the part twice daily with the tincture.

4 oz. *Zinc Ointment,* in a wide-mouthed stoppered bottle. Useful for sores, burns, scalds, &c.

3 Rolls of 1½-inch calico *bandages.*

1 Stick of *Caustic* (Nitrate of Silver,) mounted in a quill and put into a phial. Useful for sores, bites, &c.

1 Small roll of *Isinglass adhesive plaster* (*i. e.,* Court plaster). This is preferable to ordinary sticking-plaster, as the latter, owing to the heat, often becomes useless. To be moistened before application.

Care of medicines.

29. As several of the powder-medicines deteriorate greatly when kept in paper packages, and frequently, owing to damp, &c., become useless when thus previously weighed out, it is recommended that phials should be adopted in all cases and the doses weighed as required; a pair of small scales and a 2-oz graduated glass measure being packed with the medicines. A small tin box, divided into compartments, could readily be devised; and the whole need not weigh more than 8 or 10 pounds.

### APOTHECARIES' WEIGHTS AND MEASURES.

*Solids.*

| | | |
|---|---|---|
| 20 | grains | = 1 scruple. |
| 3 | scruples | = 1 drachm. |
| 8 | drachms | = 1 ounce. |
| 12 | ounces | = 1 pound. |

*Fluids.*

| | | |
|---|---|---|
| 60 | minims | = 1 fluid drachm. |
| 8 | drachms | = 1 fluid ounce. |
| 20 | ounces | = 1 pint. |

### APPROXIMATE FLUID MEASURES.

| | | | |
|---|---|---|---|
| 1 | minim | = about | 1 drop. |
| 1 | fluid drachm | = | 1 teaspoonful. |
| 2 | „ drachms | = | 1 dessertspoonful. |
| 4 | „ drachms | = | 1 tablespoonful. |
| 1 | „ ounce | = | 2 tablespoonfuls. |
| 2 | „ ounces | = | 1 wine-glassful. |

## SECTION III.—CARE AND TREATMENT OF ELEPHANTS.

Necessity of supervision.

1. In many parts of India and Burma elephants are almost indispensable for Topographical survey parties, and as both the purchase and keep of these animals form a somewhat heavy charge, it is very desirable that executive officers should themselves exercise a careful supervision over their treatment in order to ensure their efficiency.

2. It would be impossible to enter here into all the diseases to which elephants are subject, but there are two which are the most frequent cause of temporary disablement, and which are generally preventible by reasonable care. These two are, (1) injuries to the feet, and (2) sore backs.

Two principal causes of disablement.

Injuries of the feet are very liable to occur in marching over ground from which bushes and small jungle have been cut down, with short sharp stumps left standing in the ground An elephant treading on these, or even on small sharp pieces of stone, may cripple itself more or less: when such a road has to be traversed it is a good plan to harden the soles of the feet by the application of a paste, of which the ingredients are known to mahouts, and generally used by them for this purpose.

3. There are two kinds of disease peculiar to the feet of elephants, named "Tawakh" and "Sarjan". They are both contracted through neglect, and from allowing the animal to stand for many consecutive days on the same "tahan" without cleansing it. The best treatment is by nitric acid, applied with thin strips of copper, which should be dipped into the bottle containing the acid, and rubbed over the wound. The feet must be well pared and washed first; the acid should be applied morning and evening.

Injuries to the feet, and their treatment

4. One of the best native remedies for "Sarjan" is the following:— "Tua" or "Chowdara", one fruit, cut up, powdered, and mixed with one seer of mustard oil; this must be kept on the fire until it burns, and becomes thick and black The mixture is spread over the wounded surface whilst it is quite hot. An ordinary paint-brush is the best means of applying it.

*Continued*

Carbolic lotion is useful for dressing wounds on the feet of the elephant, and should be applied on plugs of tow inserted in the wounds after they have been carefully cleaned out, and all proud flesh cut away.

5. Sore backs are generally caused by the padding being out of order, in consequence of which the loads press directly on the back, and thus occasion inflammation, and very frequently suppuration to an extent that sometimes require months to cure. If on the first symptom of a swelling being

Sore backs, their cause and treatment

observed, the place is well fomented and rubbed, a sore back may probably be avoided. But mahouts, as a class, are proverbially unobservant and heedless in the performance of their duties; and the chances are that the swelling will not be noticed by them, until it becomes so large that it is impossible to avoid seeing it. The mischief is then done, and suppuration, which must be allowed to take its course, has most probably set in. These suppurating abscesses usually take place a little behind the tips of the shoulder blades. When they are quite ripe they should be opened with a long lancet-shaped knife, four incisions in the lower surface being made—two on either side. It is better to open them thoroughly at first, otherwise the pus is liable to find its way into the surrounding cellular tissue, and an enormous diffused abscess is the result. After the matter has been well pressed out, the cavity should be thoroughly syringed with lukewarm water, twice a day, morning and evening—the cavity being filled between the syringings with tow steeped in carbolic acid lotion of the following strength, *viz.*, 1 oz. of carbolic acid to 10 oz. of water. The wound should be constantly protected by a broad pad of cloth, otherwise its cure will be considerably retarded by the habit elephants have of blowing dust or dirt over their bodies—more particularly when they have sores on any part of them.

Elephant gear described

6. In the case of sore backs prevention is easier than cure, and as the "gadhela" or pads are generally the cause, too much attention cannot be given to ensure their being kept in a proper condition. They are very liable to become rotten when exposed to rain, and should therefore be always kept under cover when not in actual use; a single month of monsoon weather is sufficient to destroy them, if recklessly exposed to it. The pads and other furniture at present in use for the elephant are as follows:—

1st. The "namda" which consists of hair well felted together, is about an inch thick, and two yards square, and has a covering of gunny on the upper side, and one of coarse cloth on the under. The latter comes in immediate contact with the animal's back.

2nd. The "gadhela" placed on the top of the namda, consists of two bags of gunny filled with bulrushes, a foot thick, and two feet broad, the length being four to five feet, according to the size of the animal These bags are joined edge to edge at either extremity, the open space between them being intended to receive the spinal ridge of the animal's backbone.

3rd. The "Nímgadhi", which is of similar construction to the gadhela, but smaller in its dimensions.

4th. The "jhúl" a coarse cloth consisting of gunny which is thrown over the whole.

5th. A rope about one inch in diameter by which the above are fixed on the back—one end of this rope is converted into a loop, sufficiently long nearly to surround the body of the animal and the pads. It is tied on the top, then passed singly round the neck, then along the upper sides of the pads, then below the tail, and finally tied again at the place of the first knot on the top. The parts which pass under the belly and tail are sheathed with leather, to prevent abrasion of the elephant's skin.

Stoppage of attendants' pay

7. It may be assumed as a principle that sore backs and injuries to the feet of elephants are the result of negligence on the part of the attendants, and it is therefore a good rule to enforce, that so long as the animals are under treatment for such injuries, half of the attendants' pay should be stopped; unless good cause can be shown, in individual cases, why the rule should not be put in operation.

Head pads.

8. Elephants are occasionally very useful in pushing down trees; when so occupied pads should be provided to defend their heads. If an elephant bruise or injure itself when so employed, and this it is liable to do, it will probably refuse to give assistance again in this way.

Elephants to be picketed in the shade.

9. Elephants should not be picketed out in a burning sun; inflammation of the brain, and other similar diseases may be caused by such exposure. If shade be not available a white padded covering should be fastened over the head.

Precautions against chills.

10. On coming off a march, an elephant should be allowed to cool previously to being washed; negligence in this particular is apt to occasion serious illness. The animal may be allowed to drink water when in a heated state without any untoward effects resulting, but it should not be allowed to throw water over itself.

Watering elephants.

11. Elephants should be watered twice daily; at each time they take about 15 or 16 gallons of water. They prefer river water to all others, and willingly drink that procured by digging holes in the sandy beds of rivers, after it has stood for a few minutes to allow the sediment to sink. Elephants cannot be kept with impunity for more than 24 hours without water.

## SECTION IV.—EQUIPMENT, NATIVE ESTABLISHMENT, &c.

Constitution of native establishment.

1. The entertainment of low caste men for the greater portion of the native establishment such as "kahárs", "koris", "chamárs" &c., is advisable, though it is useful to have a small proportion of Brahmins and Muhammadans. Young hands should be entertained for survey work, and executive officers should be careful not to employ old men, unless of superior attainments and merit. Every khalási should be provided with a service book on joining. All inefficient men should be discharged at the close of the field season. Others not absolutely required in recess-quarters, or at the field depôt, may be allowed leave of absence during the recess on such portion of their salary, not exceeding half, as may be deemed advisable by the executive officer, to induce them to return to the party at the commencement of the next field season; a certificate to this effect being furnished to each man, showing the date and place ordered for his return. This leave does not constitute a break in service. D. O. (G.T dated 1st Oct 1857.

Four, or at most five, men are sufficient for a sub-surveyor when plane-tabling; but it is usual to give surveyors and assistant surveyors six khalásis. Of course for an officer employed on triangulation or reconnaissance a much larger staff, probably not less than twenty men, will be required.

Guarding stores

2. Stores and public property should not be kept in a closed tent, with a single sentry outside; for such an arrangement is unsafe, and unfair to the man on guard. The most secure method of guarding property is to collect it in an open spot, from which the sentry can have a clear view on all sides; the articles should be raised above the influence of damp ground and of white ants by means of stones and bricks. Delicate instruments liable to injury from exposure can be guarded securely if placed in a D. O (G.T.S.) dated 16th July 1850.

"shuldári" or open "pál." When the strength of the guard is insufficient for furnishing a double night sentry, the khalásis of the establishment must take their turn of such duty.

Office work when marching

3. Assistants are not exempted from all office work for the days on which they may have marched. The daily office hours will be regulated with due consideration to the length of the day's march, and to the exigency of the work in hand. Every detail concerning the arrangement of camps and order of marching is under the control of the officer in charge of the party.

D O. (G T S.) dated 29th May 1855.

Duration of field season.

4 The field season generally commences about the 15th of October, and lasts about six months, but there are few districts in India where this whole period can be utilized. In malarious tracts little benefit is gained by commencing field work before the middle of December, and in others, such as Rajputana, out-of-door work becomes almost impossible for Europeans after April. In Burma little in the way of triangulation or reconnaissance can be done after the middle of March, owing to the dense haze which obscures all distant points. Executive officers must apply for orders from the Surveyor General, or the Deputy Surveyor General of their branch, as to the times of taking and leaving the field. They are on no account, unless by special sanction, to return to recess-quarters until all the instruments and stores have been properly stowed away in the field depôt, and all accounts with the field establishment properly adjusted.

Equipment of a Topographical party.

5. The equipment of a Topographical Survey party should be somewhat as follows, modified of course when necessary, to suit special conditions :—

1 Large office tent.
1 Small ditto.
1 Shuldári for every 8 menials, office tables, chairs, &c.
1 14-inch theodolite and stand, for purposes of extension.
3 Smaller theodolites with stands, for traversing and interior work.
1 12-inch heliotrope and stand.
18 6-inch or 8-inch heliotropes and stands.
2 Observatory tents.
2 Boxes fitted with stationery, maps &c., for recorder's use at the stations.

4 Gunter's scales.
4 Beam compasses.
2 Graticule plates.
3 Steel straight edges, 36-inch.
1 Circular brass vernier protractor.
4 „ „ protractors, common sort.
4 Cardboard circular protractors.
1 Box of curves (French).
2 Planimeters.
1 Pantagraph.
1 Aneroid barometer.
1 Mean time chronometer.
1 Universal sundial.
2 Prismatic compasses.
1 Pair magnetizing bars.
3 Hand-lens, 3½ inches diameter.
2 Common thermometers
2 Sets Marquois scales (metal).
2 „ plotting scales.
1 Sextant, 6-inch.
2 Artificial horizons.
2 Metallic tapes.
1 Set of steel standard bars, 6 feet.
1 Parallel ruler on rollers, 24-inch.
2 Perambulators, or subtense bars (10 feet), according to the nature of the country.
2 Copies of the Manual of Surveying for India.
1 Hand-book of the three Branches bound together.
1 Hand-book of the Survey of India.
1 Hand-book of topographical drawing.
3 Shortrede's Log Sines and Tangents.
3 Hutton's Logarithms.
3 Chambers's Logarithms.
1 Auxiliary Tables.
1 Hints to Travellers.
1 Nautical Almanac.
2 Boileau's Traverse Tables.
2 Shortrede's „ „
2 Gurden's „ „

2 Tables fitted with tracing pane.
2 Tracing glasses.
Type, type-holders, drawing pins, &c.

Also for each plane-tabler.

1 Plane-table and stand.
2 Sight-rules.
2 Magnetic compasses.
1 Umbrella.
1 Clinometer.
1 Height Indicator on cardboard.
1 Chain and arrows, 100 feet.
1 Village book.
1 Telescope or pair of binoculars.
1 Box of drawing instruments.
1 Box of colours.
1 Parallel ruler, 12-inch.
1 Auxiliary Tables.
1 Hand-book Topographical Branch.
1 Moore's Family Medicine.
1 Set Latitude and Longitude scales.
1 „ Boundary cards.

Also the following spare articles with the Head-Quarters camp:—

8 Plane-tables.
4 Plane-table stands.
4 Sight-rules.
4 Magnetic compasses.
4 Clinometers.
12 Height Indicators on cardboard.
2 Chains and arrows.
2 Telescopes.
2 Binoculars.
2 Umbrellas.
20 Tale squares.
Portfolios large and small.
Tin tubes for maps.

This does not pretend to be a complete list of all that can be wanted by a Topographical party, but merely to serve as a guide to an executive officer to assist him in drawing up his indent.

## CHAPTER IV.

# Trans-frontier Reconnaissance.

### SECTION I.—PRELIMINARY REMARKS.

1. Trans-frontier reconnaissance differs from ordinary topographical surveying mainly in two ways. Firstly, the time at the disposal of the surveyor is usually limited and his movements confined to certain lines of advance, and secondly, there is not the same necessity in such reconnaissances for the minute accuracy which should characterize a topographical survey.

Scale.

2. As trans-frontier reconnaissances are essentially made for geographical and military purposes, minute detail is of comparatively small importance, consequently a smaller scale is permissible for the map than would be the case in a European country, of which geographical maps are always available and where minor detail is of more importance. In deciding upon the scale to be employed the choice will naturally be regulated by the extent of the area which the operations are likely to cover, the rapidity with which it will probably be traversed and the size of the prevailing features of the country.

Experience has shown that, except for special occasions, the scale of four miles to one inch is practically the most useful for general work in open countries such as Afghanistan. On this scale all the detail which there is time to sketch in hurried operations can be shown, while at the same time the plane-table sheet covers a large area and includes fairly distant hills, a very important point in work of this nature. Should minute traversing be necessary *en route*, it can be easily plotted on a larger scale and then reduced and entered on the plane-table sheet.

Necessity of triangulation.

3. The necessity of basing all trans-frontier work on triangulation cannot be too strongly insisted on. As triangulating, when time presses, is difficult and laborious, there is a strong tendency to drop it in advancing rapidly across the frontier and to adopt some easier and less accurate method of survey. This is a great mistake; for the possibility has been proved, even when moving with an army in the field, in treeless countries such

as exist on our North-West Frontier, of executing a triangulation which will be of enormous assistance to the survey.

The advantages of having such a triangulation are numerous. By means of it, plane-tabling by interpolation from fixed points—by far the most rapid and accurate method of sketching—can be executed, the latitudes and longitudes of all the fixed points are obtained and are available to plot at at any moment on any sheet and on any scale; the work is sure not to accumulate any appreciable error; the compilation of sketches made by different persons is enormously facilitated, as they can be adjusted with correctness relatively to one another even when they do not touch; very distant points can be fixed with sufficient accuracy from comparatively short bases; and heights can be accurately determined. Topographical detail will be naturally surveyed by means of the plane-table.

## SECTION II.—EQUIPMENT.

Equipment.

1. A complete equipment of the most approved type is kept up for issue to survey parties operating with an army in the field; but as it may often fall to the lot of a survey officer to select his own instruments, a few hints derived from practical experience may be found useful.

Theodolite.

2. A 6-inch transit theodolite reading to 10 seconds is the most useful; if fitted with micrometers in the eye-piece for subtense work, so much the better. One should be selected which has the level on the vertical verniers and not on the telescope, and in which the vertical verniers are not obstructed by tangent-screws in front of them, otherwise there will be difficulty in illuminating them at night. Some of the newer theodolites have glass diaphragms with cross-lines cut on them; these are not so good as those of the old pattern, as dirt collects on the glass and obscures the view of faint distant objects. The theodolite should always be packed in two boxes, the horizontal circle in one and the vertical circle in the other, as the instrument has often to be slung across a mule or carried up a high hill on men's backs.

Stand.

3. The stand should be a braced folding tripod. In selecting one for use, the chief points which should be attended to are, that the heads of the legs can

be screwed up so tight that the whole stand becomes absolutely rigid and that the feet are so shod that there is no possibility of the shoes working a little loose and so introducing an element of unsteadiness. The long conical iron shoe, such as is used on plane-table stands, gives great trouble in this respect.

Spare screws and nuts for the head of the stand should, if possible, be taken as they are apt to break or fall off and get lost. The nuts of the new pattern stand are kept on by a split pin; in other cases it is advisable when marching to tie the stand up in a bag to avoid the possibility of the loss of the nuts. A spanner to fit any nuts on the head of the stand should be taken.

Plane-tables.

4. The usual survey pattern 24 × 30 inch plane-table with folding stand is generally most useful. If, however, the expedition is over a strictly limited area, such as the late Black Mountain Expedition, a smaller and lighter plane-table, about 24 × 20 inch, may be found large enough and is much more portable. All plane-table screws should be interchangeable, and a few spare ones should be taken as well as spare bolts and nuts for plane-table stands.

Whatever pattern of sight-rule is taken, it should have the ruler portion fitted into a wooden case to protect the edge from injury, and if the sights are folding and kept up by springs, spare springs should be taken.

Heliotropes.

5. A few light heliotropes are required to mark points that could not otherwise be observed, and for this purpose the light cavalry heliograph answers very well.

Chains.

6. As it may be necessary, at any time, to measure a base, steel chains of 100 feet length should be taken, the number depending on the size of the party, and also a steel 100 feet tape as a standard of length with which to compare the chains.

Telescope.

7. A good reconnoitring telescope is most useful, though to get the maximum value out of it, it should be fitted on to a stand, such as a light prismatic compass stand.

Distance measuring instruments.

8. Some method must be arranged of measuring the distance along the routes, as a traverse of the route passed over will usually be required as a basis for the

topography. The instrument selected for this purpose will depend on the nature of country passed through, on the rate of marching, on whether the march has to be made along a road among baggage animals, and also a good deal on the predilections of the surveyor.

The distances may either be measured directly by means of a perambulator, or indirect measurements may be made with a subtense instrument, subtense theodolite or ordinary theodolite in conjunction with a subtense bar.

The relative advantages of the various methods will be dealt with hereafter. Waugh's pattern perambulator is that usually issued; it is a heavy, clumsy instrument, but can be depended on not to get out of order.

The subtense instrument consists of a telescope with micrometer eye-piece mounted over a large prismatic compass, and is used in conjunction with a subtense bar of known length.

Heights.

9. As it is difficult to fix many heights trigonometrically and as it is necessary, occasionally, to determine an initial height from which to extend the trigonometrical heights, as was the case on the Afghan Boundary Commission, some height measuring instruments must be carried: the choice lies between barometers and boiling-point thermometers, and as both are very unsatisfactory, aneroids are almost invariably used for the purpose on account of their convenience. They are however worse than useless if employed for any length of time without being checked against a mercurial barometer. Consequently the equipment should consist of several aneroids graduated to work up to a sufficient height, and one or more of George's mercurial barometers. The latter are carried empty and only filled when a reading is required, so that with ordinary care in carrying they are fairly safe from breakage.

Angle books.

10. A good supply of angle-books should be taken. A special form is made for recording both horizontal and vertical angles in one opening. If it is likely that there will be much triangulation the ordinary three-vernier horizontal angle-books are preferable: they can be equally well used for vertical angles, and hold much more than the special angle-books. Angle-books for astronomical observations should be taken, as well as a plentiful supply of computation forms, both for ordinary triangulation and for astronomical work.

Strongly bound blank ruled foolscap books are most useful for recording all irregular work and computations, instead of working on loose scraps of paper which sooner or later get lost.

## SECTION III.—ASTRONOMICAL OBSERVATIONS.

Commencing a survey.

1. In starting a trans-frontier survey from the beginning, a base from which to extend the triangulation must first of all be obtained.

In India, thanks to the Great Trigonometrical triangulation, and to the various extensions of it executed by the Topographical survey, bases are as a rule ready to hand; but in trans-frontier work it will be necessary to measure one.

This is often a somewhat troublesome undertaking. Two intervisible points a mile or more apart, the ground between which is suitable for accurate chaining, must first be fixed upon and the ground cleared as much as time allows. If there is any choice allowed in the position of the base, it is better to adopt that which affords the greater facilities for extending the triangulation by fairly symmetrical triangles, even if doing so involves the necessity of chaining over somewhat inferior ground. An error in the measurement of the base may possibly be corrected afterwards, when there is time and opportunity for measuring a fresh base in a more favorable spot; whereas, even if the base be measured with the utmost accuracy, the results will be unsatisfactory if the extension is not judiciously planned and executed.

During the Afghan Boundary Commission Survey, owing to the difficulty of getting sufficiently good ground for chaining, the bases were seldom more than 1 mile in length. They were always measured with a steel 100 feet chain, checked before and after measurement against a steel tape. Two measurements if they agreed within 5 feet per mile over bad ground were considered sufficient, but when the ground was good a closer agreement was expected.

When it is impossible to get ground capable of being chained over with fair accuracy, one or other of the subtense methods of determining the length of the base must be employed. If the ground is well suited for the purpose, measurement with a chain has certain advantages over subtense measurement, especially if the chainmen are experienced; for as soon as the ends of the base are marked, the observation of the angles may be commenced and meanwhile the base can be chained.

The base being measured, or under preparation for measurement, it is necessary to observe its true bearing or azimuth, and the latitude of one of its ends. To obtain the latitude it is necessary to know the local time with fair accuracy, so that three classes of observations must be taken, *viz.*, those for latitude, time, and azimuth.

Astronomical observations.

2. With regard to astronomical observations in general with a small theodolite, it is best invariably, except when on rock, to drive into the ground three strong wooden pegs, on the heads of which the feet of the theodolite may rest. It is wise if possible to do this by daylight, as it takes a little time to get the pegs so driven in that the theodolite can be levelled without doing violence to the foot-screws.

The adjustments of the eye-piece for distinct vision of the wires, and the object-glass to solar focus so as to eliminate parallax, should also be performed during daylight, as they are very difficult to do at night.

The wires may be illuminated either by the small axis lamp placed opposite the end of the perforated axis or by throwing a light on a narrow strip of stiff white paper, such as a piece of a map or visiting card between $\frac{1}{10}$ and $\frac{2}{10}$ inch wide, secured by a piece of thread or an india rubber band and bent across in front of the object-glass at an angle of about 45°. The strip should be long enough to go across the object-glass. The light is thrown on the paper from a bull's-eye lantern held by an assistant, and reflected down the telescope on to the wires. This arrangement is much more satisfactory than the axis lamp which often refuses to burn if there is any wind, and never gives a good light except under the most favourable conditions. It also gets into the observer's way when he wants to read the horizontal vernier underneath it.

The process of getting the star into the field of the telescope is much facilitated by fixing on the telescope rough fore and back sights with their tops aligned parallel to its axis.

The barometer and thermometer must be read and recorded to enable the correction for refraction to be calculated, but no great exactness of reading is required.

When reading the horizontal verniers at night it will be found advantageous to read them from the side, so as to be able to throw the light straight on to the verniers in a line with the graduations.

A sidereal chronometer is convenient if a number of observations have to be taken; but unless there is the chance of having to take

some delicate observations, such as longitude by telegraph, it is hardly worth the trouble of carrying one. For all practical purposes, a fairly good watch with a seconds hand does well enough, but it must be such that the seconds hand completes its revolution as the minute hand covers each minute mark and that it does this *at all parts of the hour*, otherwise there will be trouble in settling which is the correct minute.

In observing stars with a watch it is simplest to treat it as a sidereal watch with a large rate, as by so doing the trouble of reducing the results into mean time is avoided.

Observations.

3. It is only necessary to touch lightly on the methods of observing for time, latitude and azimuth as it is assumed that surveyors are all well acquainted with the manipulation of theodolites. It is however strongly recommended that they should make themselves thoroughly familiar with the various astronomical observations and computations *before* they are ordered on trans-frontier expeditions.

Time.

4. For the computation of latitude observations it is necessary to know the local time with tolerable accuracy; for azimuth it may be required more accurately.

The usual and the most convenient way of obtaining the local time from the stars is to observe one star to the east and one to the west and take the mean of the values obtained. The object of observing two stars on opposite sides of the meridian is not only that one may check the other but also to eliminate errors in refraction.

Two stars should be selected which are moving rapidly in altitude and are at a convenient elevation above the horizon, say 20° to 50°. The stars on or near the prime vertical (that is, due east or west of the place) will be those which are moving most rapidly in altitude.

The process of observing is as follows:—The instrument being properly levelled, the star is brought into the field of the telescope and the vertical circle clamped with the horizontal wire a little in advance of the star; the exact moment by the watch of the star crossing the wire is noted and the readings of the ends of the level bubble and of the verniers of the vertical arc taken and recorded. The face is then changed and the process repeated.

This forms one complete observation, and it is advisable to take two such to each star, the usual order being one face left, two face

right, one face left. The mean of the whole lot, corrected for any dislevelment of the instrument, is used for purposes of computation; but should the results from two stars disagree, the observations to each star can be split up into two and by this means the error probably discovered. Unless there is some mistake in the observations the values of the watch error deduced from the two stars by observations with a 6-inch theodolite should agree to within two seconds and will probably be much closer together; though, if they agree to within five seconds, the mean is probably close enough to the truth for latitude computations.

Should great accuracy be required, it will be found that better results can be obtained by observing fainter stars of the 2nd magnitude rather than very bright 1st magnitude stars. Of course the sun can be observed for time in the same way as a star, except that there are one or two more corrections to be applied in the computations.

Latitude.

5. The quickest and simplest way of obtaining the latitude is by observing the altitude of the pole star and noting the watch time of observation. The watch error must be ascertained by finding the time as described above. When the watch error is known, the local sidereal time of observation can be determined; and knowing this the latitude can be found from tables in the Nautical Almanac.

The accuracy with which it is requisite to know time for this computation varies with the position of the star in its course. Where it is at its culminations, that is, at its highest and lowest points, it moves very slowly in altitude and a considerable error in the time would affect the result little. However it moves so slowly at any time that if the time has been found from the sun or stars, the result is sure to be close enough for any part of its course, and it is not worth while to incur the possible inconvenience of catching the pole star at one of its culminations. When the star is moving most quickly in altitude an error of 3 seconds in time will cause about 1 second of error in latitude; so it can be seen that some 10 seconds of error in time is admissible always.

The most accurate method of getting the latitude consists in observing north and south stars, on or near the meridian, in pairs of about equal altitude. Except in the case of the pole star, what are called circum-meridian observations are necessary, and for the computation of these there is a special formula. The length of time before and after

transit for which this formula holds good, varies with the position of the star. As a rough rule, stars should not be observed within 20° or 25° of the zenith and should be within 20 minutes in time of their meridian passage. The object of the observations is to obtain a series of altitudes of the star, at known times, about the time of its transit across the meridian. The observations must of course be taken in pairs face left and right. It is sufficient to take three or four pairs and it is as well that they should be fairly divided, some before and some after transit but this is not absolutely necessary. When the error of the watch is known beforehand, it is easy to determine the watch time of transit and commence the observations accordingly. If however it is not known, it is best to set up the instrument as nearly as may be in the meridian by its compass, and then see when a star is sufficiently near the meridian to commence observing.

It is a convenient method of determining the latitude to use the pole star as the north star, and to balance and check it by observing a circum-meridian star to the south, as nearly the same altitude as the pole star as can conveniently be obtained.

With a 6-inch theodolite the value of latitude obtained from the north and south stars of a pair should not differ by more than 15 seconds; and when several such pairs have been observed their means should all agree within 8 or 10 seconds, and are often much closer.

For ordinary purposes one pair of north and south stars gives a fairly good latitude. It is better however to take two pairs, as then a fair result is likely to be obtained, even if one of the observations should be vitiated by some error. There is no object in indefinitely increasing the number of pairs, six good pairs will be ample for all purposes.

Azimuth.

6. The true bearing or azimuth is obtained by observing the horizontal angle between a referring mark and a star, either at a known moment of time or when the star is at a known elevation. From either of these elements the local time of observation or the altitude of the star at the moment of observation, the latitude being known, the star's azimuth can be computed and that of the referring mark deduced.

Properly the referring mark should be at a considerable distance, say half a mile from the observer, in order that the same focus may suit it and the star. Unfortunately it is seldom possible to have it so

far away at night in an enemy's country, and generally speaking a distance of 300 or 400 yards or even less has to be adopted.

As the distance is so short it is very necessary that both instrument and lamp be centred very exactly over their marks.

It is best after having in the afternoon observed the horizontal angle from the end of the base, between the referring mark and some well defined point, to leave the theodolite stand in position till night. This saves the very troublesome operation of levelling and centering the stand at night. It is also as well to make a man sit by the referring mark till evening, as not only is such a mark difficult to find in the dark, but it is also very likely to be removed by some one. In observing, one focus should be adhered to both for star and lamp, so the focus should be adjusted for the star, and when observing the lamp the eye should be kept far back and as steady as possible so as to minimize the effect of the parallax caused by the bad focus.

The azimuth can be obtained in two ways. The first method is as follows:—Knowing the time within a second or two, the horizontal angle between the lamp and any star which is at a convenient altitude and is moving slowly in azimuth is observed, and the time noted at which the star is intersected. Circumpolar stars at or about their maximum elongation give the best results, but such stars of a suitable size are few, and it is not worth while sitting up for elongations, as sufficiently good results can be obtained by taking any two stars towards their elongation, which are on opposite sides of the meridian and fairly near, say within 45° of the pole.

The actual observation is taken in the order:—lamp, star, star, lamp; then the face is changed and the observation repeated on the other face.

By taking the means of all the observations a mean horizontal angle between the star and the lamp, and a mean time of observation of the star is obtained. From the mean time of observation, knowing the declination of the star and the latitude, the star's azimuth at the time of observation is computed, and by applying the observed angle the azimuth of the referring mark is obtained.

The second method avoids the necessity of knowing the true local time. It involves getting both the horizontal and vertical readings of the star for the same instant. To do this it is necessary to make the star pass through the intersection of the cross-wires. From the altitude of the star its azimuth for the same instant can be computed; so by observing in the same manner as by the first method, except that the star is made to pass through the intersection of the cross-wires,

and the elevation instead of the time of intersection recorded, the same result is obtained. If in addition the time of the star crossing the wires is noted, all the elements necessary for computing the time are available, and the computation will be an easy one, as the figures will be nearly the same as in the azimuth computation, only arranged differently.

This method saves time and work when it is necessary to observe for time, latitude and azimuth on the same night. It is not quite so easy as the first observation and requires a little practice to make the star pass through the intersection of the wires. The best way to work it is to set one wire—the horizontal one is perhaps the best—in advance of the star, and then by moving *the tangent-screw of the other wire only*, to place the intersection of the wires so that the star will pass through it.

The stars selected for this observation should be of a convenient, but not high, altitude and rather north of the prime vertical. Observations should be taken as usual to both east and west stars and the mean result used.

Azimuths can also be taken from the sun; but in this case it is better not to attempt the simultaneous observation but to observe for time first, and then take the horizontal angles to the right and left limb.

As the azimuth will be affected by the angles of the triangulation, there is no advantage in observing a lot of stars so as to get an azimuth within 2 or 3 seconds of the truth, when, whatever precautions may be taken, the triangulation is sure to contain angles that are incorrect to the extent of 15 or 20 seconds, or even 30 seconds, on account of the ill-defined nature of the points observed. It is better to take any good opportunity of observing fresh azimuths which can be connected with the triangulation, so as to prevent the accumulation of azimuthal error. The azimuth of the referring mark deduced from two stars should agree within 20 or 30 seconds, and if the stars have been well chosen and the observations carefully taken, the agreement will be much closer.

## SECTION IV.—TRIANGULATION.

Method of carrying on triangulation.

1. In choosing a base there is little use trying to select naturally marked points for its ends. It is sure to be on low ground, and when observations are made back to the ends from one of the hill stations, it

will be impossible to recognize them unless they are marked by some very conspicuous artificial object such as a heliograph. The minimum length for a base may be taken as half-a-mile, the maximum will depend on the distance of the points to be fixed from it. While the ground for the base is being selected and prepared, a perambulator base of two or three miles should, if possible, be run and by means of it the positions of the surrounding prominent objects cut in on a plane-table. This having been done, the first steps of the triangulation can be laid out, the next stations selected and, if necessary and feasible, men sent out to put up marks on them to observe to.

If the precaution to ascertain the position of the surrounding hills before laying out the triangulation is not taken, it will possibly be found that it is not nearly so symmetrical as was expected, and as it might have been with the same expenditure of labour.

In observing it is a good plan to set up the theodolite always by the compass, so that the telescope points to the magnetic north when the theodolite reads 0° 0′. By this means all readings are also magnetic bearings, and it frequently assists the finding of a point which has been observed to, to know its magnetic bearing from the previous station. Another advantage is that the comparison of the computed azimuth of any ray with its magnetic reading will give the compass variation at that spot.

Unless there are very well defined points to observe to, it is useless repeating the observations; and it will be quite sufficient to take one observation face left and one face right to each object, but it must be noticed before closing work that the two readings are accordant within reasonable limits, depending on the nature of the object observed.

Another good method for intersected points is to take a round of angles on one face and then work round again on the same face, setting the theodolite to each of the recorded readings in succession, and then looking through the telescope to see if it is fairly on the object.

With regard to what to observe, a good rule is to observe everything that is observable. Time after time observations taken more or less by chance, or simply to carry out the above mentioned rule, have turned out most useful. Of course if the time is limited a choice of objects must be made. In this case each of the previous stations should be observed once on each face and also all points on ahead on which it is possible stations may be made; and after that observations

on one face only may be made to as many points as possible, choosing those, by preference, which from their position or well marked character afford most chance of being well fixed and of being useful when fixed. Points selected for stations must be well marked naturally, so that when they are visited it may be possible to identify, within a few feet, the point that has been previously observed.

As a rule it is best to observe the highest points of a hill, because they are nearly always the easiest to recognize. Observations are apt to be made to what appears to be a well marked bush or rock not quite on the top. Such points are always most difficult to recognize on arrival on the hill. If there is any doubt, readings should be taken to every point on the hill which is the least likely to be suitable for a station.

Should the observations have been taken to a prominent tree or rock, when the hill is visited the theodolite should be set up on the highest point and the reading of the tree or rock which had been observed to taken and its distance measured. If no tape be available or the ground is not suitable for measuring, a man should be sent to the point with a stick of known length and instructed to hold it horizontally and at right angles to the direction of the observer. The horizontal angle subtended by the two ends of the stick must then be measured, from which the distance can be computed with sufficient accuracy; knowing its distance and its reading from the theodolite, it is easy to correct all the previous observations to what they would have been if the position occupied by the theodolite had been observed. This is just as accurate as, and simpler and far more convenient than, reducing all the angles taken at the station to the position of the mark. The position occupied by the theodolite will in general be easy to recognize and observe to afterwards when the usual pillar is built.

Triangulation in forest country.

2. When triangulating in a forest-covered country, there is nothing for it, but to be content with fewer stations and to try and clear the hills as much as possible, which is a work frequently of great magnitude.

In clearing a hill one large tree should always be left standing conspicuously near the station, and during the observations a reading to it taken and the distance measured.

It often happens that either from the shape of the hill top of from the limited time available, that complete clearing is out of the question. In this case something can be done by raising the theodolite sufficiently

from the ground to allow of a clear view by a comparatively small amount of lopping of the branches of the surrounding trees. The method which was employed by the late No. 6 Party, when working in the forest-clad hills bordering Assam, was as follows:—A suitable tree was selected, its trunk cut off at a convenient height, say 30 to 50 feet from the ground, and a scaffold erected round it; on this, and at about 4½ feet below the top of the trunk, a platform of bamboos was made for the observer to walk on, the platform and scaffold being quite isolated from the tree trunk.

It is seldom that a tree with a straight trunk much over 30 feet can be got, but it is manifest that the ability of placing the theodolite at that height will save an enormous amount of hill clearing. The highest to which Mr. Ogle succeeded in raising his theodolite (a 6-inch) by this means, with a perfectly isolated platform, was 45 feet. Colonel Woodthorpe, however, had on one occasion a platform built in a banyan tree for a 6-inch theodolite at a height of 107 feet from the ground. In this case it was not possible to completely isolate the observing platform, but the great size of the tree made up to a considerable extent for the unsteadiness thus caused, and the accuracy of the observations was not affected to any very appreciable amount.

Choice of points.

3. In choosing intersected points the main object should be to select such as will be of use to the plane-tablers. They do not require to be fixed with the same accuracy as stations, and it is therefore not necessary that they should be so sharply defined; but they should be conspicuous points about which, when seen by the naked eye, there can be no mistake.

When triangulation has been carried some distance, there is frequently a chance of its breaking down, owing either to non-identification of points previously observed to, or from the line of advance preventing flanking stations from being visited. When this is the case, if a station happens to be visited before 9-30 A.M. or after 2-30 P.M. it is an excellent plan to observe an azimuth of the sun if it is visible and refer it to one of the back stations. This azimuth, with the observed angle between any two well fixed points not too much in a line, will give a very fair fixing of the position of the visited station.

One of the great difficulties of this sort of work is, that there is seldom reliable information in which direction the next march will be, or which of the hills that have been seen from a commanding point is likely to be passed close enough for ascent. All that can be done is to

make out as well as possible from the guide, the direction of all the principal routes, and select points for stations along each of them. This uncertainty about movements is one of the chief reasons for the rule previously given, to observe everything.

The length of sides permissible in the triangles, depends on the height of the stations and the consequent extent of view from them; the nature of the objects to be observed; the clearness of the atmosphere; and the maintenance of sufficient symmetry. The greater part of Afghanistan and Baluchistan is very favorable for triangulation and, as far as view is concerned, it is possible, if desired, often to have triangles of 30 and 40 mile sides, and intersected points sometimes as far distant as 100 miles.

There are other considerations, however, which generally make it advisable to keep the sides between 10 and 20 miles in length. If a point is observed from a hill A, and not again till a hill B 30 miles off is reached, it is highly possible that it cannot be seen from B, or that, even though it is visible, the spot previously observed to cannot be recognized; at any rate it is unlikely that a shot from a third station will be got to it so as to fix it satisfactorily.

Again if it is eventually fixed it will have been of no assistance in mapping, as it will have been passed before its position was determined. Whichever way marching is being done, great efforts must be made to fix points on ahead in that direction to assist the plane-tabling, as the whole object of the triangulation is to assist the mapping. The points fixed on ahead for this purpose do not require to be fixed with extreme accuracy, and as a rule they will eventually be much better fixed, but it is important to get values for them as soon as possible on which to base the topography. To effect this involves observation from a good many more stations than would be required if the triangulation was first done and plane-tabling afterwards. To aid in the future recognition of the points observed to, as each point is observed, its outline as it appears in the telescope, should be carefully sketched in the angle book. After observing, the station should be marked if possible with the usual mark-stone; and if stones are available a large pillar should be built to furnish a point to observe to. A pillar as high as a man and three feet in diameter at the base can be seen a long way against the sky-line.

If observations from a point on which such a pillar has been previously built are being made, it is as well before pulling it down to make

way for the theodolite, to lay a couple of lines of stones, whose prolongations intersect at the centre of the pillar. If this precaution is not taken, it will very possibly be found that, when the pillar has been pulled down and the place littered with stones, it is impossible to tell within three or four feet where the theodolite ought to be put, unless there should happen to be a mark-stone, which is by no means always the case. Stations should always be carefully described, and if the hill is a difficult one to ascend, the best way up should be noted.

Even if the triangulator has not to do topography *pari passú* with his triangulation, he must still carry a plane-table for the purpose of keeping a triangulation chart, to assist him in identifying his points and as a graphic record of what he has done. To each point to which observations are taken, a ray is drawn, the name entered in the angle-book written along it, and on the ray a sketch of the point as it appears to the naked eye is made.

If several peaks have been observed for the first time from the top of a hill, as they will disappear from the observer's view on his descending the hill and remain hidden till some other hill is reached, very great difficulty will be found in recognizing them. If however even a rough clue to their distance can be found, their identification will be greatly facilitated. To effect this, when the observing is finished, it is a good plan to get on to some neighbouring hill fairly close, say three or four miles off, from which second plane-table rays to the intersected points can be obtained. There should be no difficulty in recognizing them, as the second point of view will be so very similar to what it was from the observing station; and though the intersections will be very acute if the points are distant, still the approximation they will give will be of great assistance in identfiying the points.

Computations should always be kept up to date, and it will be found most advantageous, in spite of the work entailed, to calculate the latitudes and longitudes of all points required for use, instead of trusting to plotting them by distances. The plotting is far more accurate; detached sketches, based on graticule plotted points, can always be put together; the coordinates of points can always be transmitted to a distance; and the distance between points not directly connected can readily be computed, which is particularly useful for interpolations.

The question of how much time to devote to topography, and how much to triangulation, is difficult to decide when both must be done by the same person. Of course triangulation is useless by itself, and if

there is no particular object why the positions of points should be known with accuracy, or preparing ground to assist other topographers coming afterwards or working simultaneously, then triangulation must be entirely subordinated to the topography, and carried out only in so far as it assists the execution of the work actually in hand.

The angular errors of triangulation vary so greatly with the nature of the country and the objects observed to, that little can be said as to their probable amounts. In favourable country, such as Afghanistan, triangular errors occasionally come out as large as 30 or 40 seconds; but in such cases there is usually something shaky about one of the angles. To assist in determining to which angle to apportion most of the error, careful notes should be made in the angle book if any observation is exceptionally good or is at all doubtful.

Heights should be freely fixed; for though the knowledge of the heights of a large number of hill peaks is not very important, they frequently enable heights in the valleys and open ground to be interpolated.

In the high and dry climate of Afghanistan and Baluchistan, the refraction is very much less than in India. Instead of ·065 or ·07 of the contained arc as in India, the mean of a large number of observations gave a coefficient of refraction of about ·05.

Work on the march.

4. When, owing to the rapidity of the march or other cause, anything approaching regular triangulation becomes impossible, it may be practicable to keep an accurate check on position by using detached bases at intervals. From each base points are intersected to the rear, which have been previously fixed from the last base, and others are fixed on ahead to be in turn intersected from the next base. With this method, it is very advisable to observe a latitude at each base, not only to prevent the accumulation of error, but in case of the connection breaking down. An azimuth is indispensable for each base. In this way, in suitable country, a sufficiently accurate connection can be maintained in whichever direction and however rapidly the force marches. The essential conditions are, firstly, that there should be two surveyors, one to do the topography and the other the triangulation, and secondly, that there should be sharp, well-marked natural points visible from each two consecutive camps. This method is particularly applicable when carrying a survey across a mountain range.

Another method is very useful when the line of march approaches north and south. Latitudes should be observed at all camps, and azimuths observed to all peaks in the line of march or nearly so. When camping abreast of any of these peaks their position must be fixed, with reference to the camp, by means of a short base with the usual latitude and azimuth. The difference of longitude can then be easily computed.

As an example of this method combined with that of short bases, a diagram is given showing the triangulation executed on the line of march of the Afghan Boundary Commission from Ibrahimabad to Kuhsan. The distance by road is 310 miles: this was covered in 16 marches, giving an average of 19·4 miles per diem. In addition there were three halts on the road; so that 19 days in all were taken in completing the 310 miles. The surveyors were not allowed to leave the line of march until after their arrival at Kuhsan, when the triangulation north of Herat was executed.

As many of the points observed from the short detached bases were afterwards included in the Kuhsan triangulation, there was an excellent opportunity of judging the merits of work executed from these short bases, often not more than half-a-mile in length. The conclusion come to was, that as long as there were well-defined points to observe to, the system was capable of great accuracy.

Trigonometrical interpolations are often very useful, but to insure their accuracy, it is necessary to have three very well fixed and properly situated points. Where there is any doubt as to minute accuracy of the points, and it is desired to interpolate the position from them, it is best to observe an azimuth to one of the points from the place; then not only the angles between the various points, but also their true bearings, are known and it is impossible that there should be much error in the position of the interpolated point. For this purpose azimuths observed from the sun are often very convenient: it must be remembered, however, in azimuths of the sun, that if the horizontal angle is only observed to one limb, the correction to the sun's centre is the sun's semidiameter × secant altitude.

Heights.

5. When the triangulation is first started there will probably be no reliable height for the base. If so an approximate height from barometric observations must be obtained and used throughout the triangulation, all heights observed by any of the party being invariably brought into the same

terms. When eventually a trustworthy value for the datum is arrived at, either by joining on to some trigonometrical series, or to the sea, or from a continued series of barometric observations, it is only necessary to apply a constant correction to all the heights.

If possible a George's barometer should be taken; it is most useful to compare with aneroids or for a series of observations to fix the datum. As to the aneroids, the small ones of 2-inch to 2½-inch diameter seem to be just as accurate as the larger 4½ or 5-inch ones, and being so much lighter they are much less likely to be injured by a fall or a jar.

Altogether barometric heights are most unsatisfactory, and many observations taken in Afghanistan and worked out with simultaneously taken observations elsewhere, show that the temperature correction as given in text-books is excessive, the fact apparently being that in that country the temperature observed at ground level is that due to a highly heated stratum of air, and gives no clue to the temperature of the column of air immediately above the point of observation.

In taking aneroid heights along the line of march, the best plan is to read the instrument immediately on arrival in camp and then again next morning before starting, recording the times This helps to eliminate the changes due to climatic variations of pressure. During halts series of careful hourly readings should occasionally be made to get data for correcting observations for the diurnal wave of pressure. Every opportunity should be taken of checking barometric heights by comparing them with the heights brought along by triangulation. This can frequently be done by interpolating the position on the plane-table from trigonometrical points and observing their altitudes. The bases can be measured off the plane-table with quite sufficient accuracy for the purpose required.

## SECTION V.—TOPOGRAPHY.

Plane-tabling.

1. The routine of plane-tabling will be familiar to all survey officers, but there are a few points in trans-frontier work which are worth mentioning.

The great difficulty in all small scale surveying, where the fixings are usually far apart, is recognizing the ground and the points to which rays have been taken, as the features look so different when viewed from different sides. As previously mentioned, in dealing with triangulation,

it is always advisable to get approximate positions for newly seen objects by making a second fixing fairly close to the first, so as to get second rays to them before they have changed their appearance. Such approximate intersections will be found of immense value later on, in enabling the surveyor to identify the objects from a different point of view.

When the surveyor is moving from one point to another, he must have his eye continually on the points he wishes to recognize, and note every change in their appearance, otherwise he is liable to find himself in the position of having a number of rays drawn on his paper and being quite unable to make out to what they were drawn.

As the triangulated points are few, the surveyor will often find that he wishes to interpolate his position or fix himself in places from which none are visible. He has therefore to find his position by employing his previous fixings and the points intersected from them. Here, in reconnaissance work, there is scope for great judgment and experience in deciding which rays to adopt and which to reject when these differ irreconcilably, and in proportioning the accuracy of the fixings to the work required of them.

Each plane-table fixing should be clearly marked with a red dot for future reference. The knowledge of the exact spot a man has visited and fixed his position at, is invaluable afterwards in bringing various pieces of work together, and as a clue to the trustworthiness of the sketching.

It is very important that the men should be accustomed to the scale on which they are to work. Native surveyors are greatly creatures of habit, and when they attempt to sketch broken ground on an unfamiliar scale, they are for a time quite at a loss. In military expeditions time is far too valuable to waste in teaching a man his work.

Nothing should be looked on as too distant to sketch. When it is impossible to say for certain that any portion of country will be actually visited and surveyed in detail, it should be remembered that in a country of which no maps exist, any sort of guess at the lie of the country is valuable. Of course the style of drawing should be suited to the way the topography has been obtained.

When country has been sketched from single rays and estimated distances, it often supplies valuable information afterwards if rays to striking features such as peaks, gaps in ranges, &c., are inked in Even where the detail will not come on to the plane-table, such rays should be inked in, and the description of the point written or drawn on them.

The pencil rays drawn to outlying topography on the plane-table are best left in and not rubbed out for the same reason.

Plane-tabling in forest country.

2. In plane-tabling a hilly forest-clad country, to save time and expense in clearing the hills, a good method is to raise the plane-table well above the ground by means of *machâns* or platforms built in the highest trees on the tops of the most prominent hills. A *machân* is a very simple contrivance: thin pieces of wood or bamboos are laid down horizontally and lashed to the branches of the trees; this forms a frame work, over which are tied split bamboos to form the platform for the plane-table and its stand. The upper branches of the tree are lopped off to enable the surveyor to obtain a view. The *machân* is ascended by a ladder, either laid slantingly from the ground to the branches of the trees, or the rungs are tied to the trunk. There is considerable vibration when moving about, but on remaining still this ceases, and the compass is easily set, nor is the table thrown out of position in walking round it, if this is done steadily and not in jerks.

The advantages of the *machân* over clearing are, that time and expense are economized and from the raised position, a better view of the features of the country is obtained.

Should a high wind prevent the use of the plane-table on the *machân* after it is built, a prismatic compass should be used for taking careful bearings, and a note-book sketch made, all of which should be transferred to the plane-table on coming down from the *machân*.

When the late No 6 Topographical party was working in the hills in Assam and Manipur, *machâns* were frequently built, varying in height from 75 to 180 feet: the latter height was seldom attained, but 100 feet and over was of pretty frequent occurrence.

The positions of villages in forest-clad country can frequently be obtained by having fires lit near them and then cutting in the position of the smoke on the plane-table.

It is usual in India to insert numbers in place of names, and a list is made at the side showing to what names the numbers refer. This is dangerous in reconnaissance work, as numbers are frequently obliterated with the rough handling of the maps, and as a rule no opportunity occurs of verifying them again. Moreover with a map that is constantly referred to at all stages of its execution, it is far more convenient to have the names entered in their proper places on the map at once.

3 Sometimes it is convenient to measure the distance of points by theodolite triangulation and, as a temporary measure, to plot them by distance, for instance, when marching rapidly and keeping the position by perambulator or other traverse If the country is suitable for triangulation, it is quite possible for an assistant to measure a base and compute the distances of the points he has observed from it on ahead, the day of his arrival.

Topography on the line of march.

The next morning the plane-tabler, before he starts on his march, sets up his plane-table carefully, by back points or by compass, at one end of the base, and drawing rays to the various points, plots their computed distances along those rays. By means of the points thus plotted he may be able to interpolate his position along a portion or even possibly the whole of his day's march.

This frequently gives the surveyor a lift over rough, broken ground difficult to traverse. Care must however be taken to recommence traversing before getting out of reach of the triangulated points or the surveyor will find himself, as the writer once did, stranded without the possibility of fixing a point from which to carry on the traverse.

Ordinarily speaking topography along the line of march must be based on a traverse of some sort, for though, as has been described, the position from camp to camp may be carried on by various methods of triangulation, for sketching it is necessary to put up the plane-table at many intermediate points, and the simplest way of determining these points is by traverse.

In suitable ground, such as southern and western Afghanistan, where the country consists of wide, open valleys or plains and narrow mountain ranges, the best method of working is by plane-table traverse, the distances being measured by perambulator. The latter instrument in suitable ground has several advantages over other distance measuring instruments. In open ground it is frequently possible to run 4 or 5 miles without setting up the plane-table, in which case no more attention is required than to generally supervise the direction. The rest thus given will be appreciated by those who have to march some 16 or 18 miles day after day, getting in all the topography *en route*.

Another great advantage which perambulating has over subtense methods on the line of march of an army is, that the surveyor is generally confined to the exact line of march, and is frequently more or less mixed up with the baggage animals. This renders it almost impossible to get a sufficiently clear view, either forwards or back, to observe

carefully to a subtense bar. The perambulator can however be wheeled along comfortably.

With a perambulator in easy country, a good sketcher can average 16 miles a day for a length of time, and can occasionally do 20 miles a day, taking the day at 11 hours; that is to say, the surveyor can keep up with laden camels and therefore do his day's work without ever getting behind the rear guard, a very important consideration.

When ground is unfavorable to the use of a perambulator, one of the subtense methods of measuring distance must be employed. Of these there are two which have both been used with much success, one measures the angle subtended by a bar of known length by means of a telescope with a micrometer eye-piece, the other measures the angle on the limb of the theodolite itself. The former instrument in its most convenient arrangement takes the form of a theodolite telescope with micrometer eye-piece mounted over a good prismatic compass on a firm stand. Thus the bearings and distance can be observed with the same instrument. This method was used with great success by Colonel Woodthorpe in Chitral, where he did as much as 18 or 19 miles a day with very satisfactory results as regards accuracy. The instrument however measures direct and not horizontal distance, though this is more important to a surveyor than to a reconnoitrer.

In the second method referred to, the bar is held horizontally and its subtended angle is measured on the horizontal circle as follows:— The vertical wire of the theodolite is brought on to the left end of the bar and the reading recorded; the wire is then moved by the slow-motion screw of the upper plate on to the right end of the bar, but no reading is taken. Leaving the upper plate clamped, the telescope with both plates is brought back by means of the lower plate slow-motion screw till the wire again falls on the left end of the bar. The right end of the bar is again intersected by means of the slow motion screw of the upper plate. This process can be repeated a number of times with great rapidity, and then the final reading of the right hand end of the bar is recorded. There are then, after say $n$ observations, the initial reading of the left hand and the final reading of the right hand end of the bar. The difference between the two readings divided by $n$ will give a good measure of the angle subtended and from it of the distance required.

The two readings mentioned are the only ones really required; but as a precautionary measure, to give a check, it is a good plan to record also the reading of the right end of the bar the first time it is

taken. The difference between the readings of the two ends of the bar will give a rough value for the subtended angle, sufficiently near to expose any error in counting the number of times the process has been repeated. Tables are provided showing the distances corresponding to the various subtended angles for bars of 10 feet and 20 feet in length. The advantages in point of accuracy of this method are, that not only a considerable number of intersections of the ends of the bar are obtained, but the uncertainties of reading the limb, which with a 6-inch theodolite may easily amount to 10 seconds, each time the instrument is read, are minimized, the errors of two readings only being divided among 10 measures of the angle.

In flat jungle country, route surveying can be frequently carried on along the beds of shallow streams, the measurements being most conveniently made by means of canes. Lengths of 100 feet are easily procurable in cane growing countries such as Assam. The canes being light are capable of floating on the surface of the water and are easily pulled taut by the chainmen. They also possess the advantage over ropes and chains that they are easily drawn through forest and jungle undergrowth without being caught by thorns in the bushes. The best description of cane to use is the thin one from 1½ to 2 inches in circumference.

Rough methods of topography.

4. When none of the accurate methods of measuring distance are available, the surveyor must fall back on pacing, timing his march, or some other means of determining the distance passed over. The method of counting one's paces is a very tedious one and should only be resorted to when absolutely necessary, as when marching through narrow forest paths where the interruptions to the march are frequent.

Where the march is conducted without frequent halts, the system of timing the march—especially if riding—is better and more accurate. Timing demands a good deal of attention, but not nearly so much as pacing does; it is consequently less likely that any gross error will creep in.

In reconnoitring in a country where a regular plane-table and stand cannot be used, every effort should be made to sketch the ground at the time of passing through it and the surveyor should not trust to recording it in a note-book and plotting it afterwards.

The cavalry sketching case, which consists of a small board some 6 or 7 inches square with an arrangement for holding paper and with a

small magnetic compass fastened on its edge, is an excellent instrument for route sketching. It should be used in conjunction, when possible, with a prismatic compass, the bearings to the more distant or important points being taken by the latter and plotted on the board, while the topography is sketched directly on the board. The advantage of the arrangement is that the board can always be held properly in azimuth by means of the compass on it, so that the sketching on it occupies its true relative position.

In surveying rapid shallow streams flowing through dense forest where, owing to the rapid flow of the water, it would be difficult, if not impossible—without cutting lines along the banks—to use canes for measuring, a good plan is to use "dug outs" (country boats hollowed out of a single tree) and take bearings by means of a prismatic compass suspended in gimbals; then to measure certain distances along the bank and note the time the boat takes to pass over them, carried down by the current only. This will give a scale of distance by time and the route survey can then be roughly carried on, the compass giving direction, and the watch the distance.

In marching along narrow forest paths where the view was so restricted that it was impossible to take continuous bearings of the route, Colonel Woodthorpe found it a good plan to estimate the direction of the route by observing the direction of his shadow or of that of the man in front of him—an occasional bearing being taken to check the bearing of the shadow.

Whatever method of sketching the route is adopted, the smallest opportunity should never be neglected of obtaining any check on the work, either by astronomical observations, the intersection and re-intersection of distant peaks, or bearings to known points.

Finishing up work.

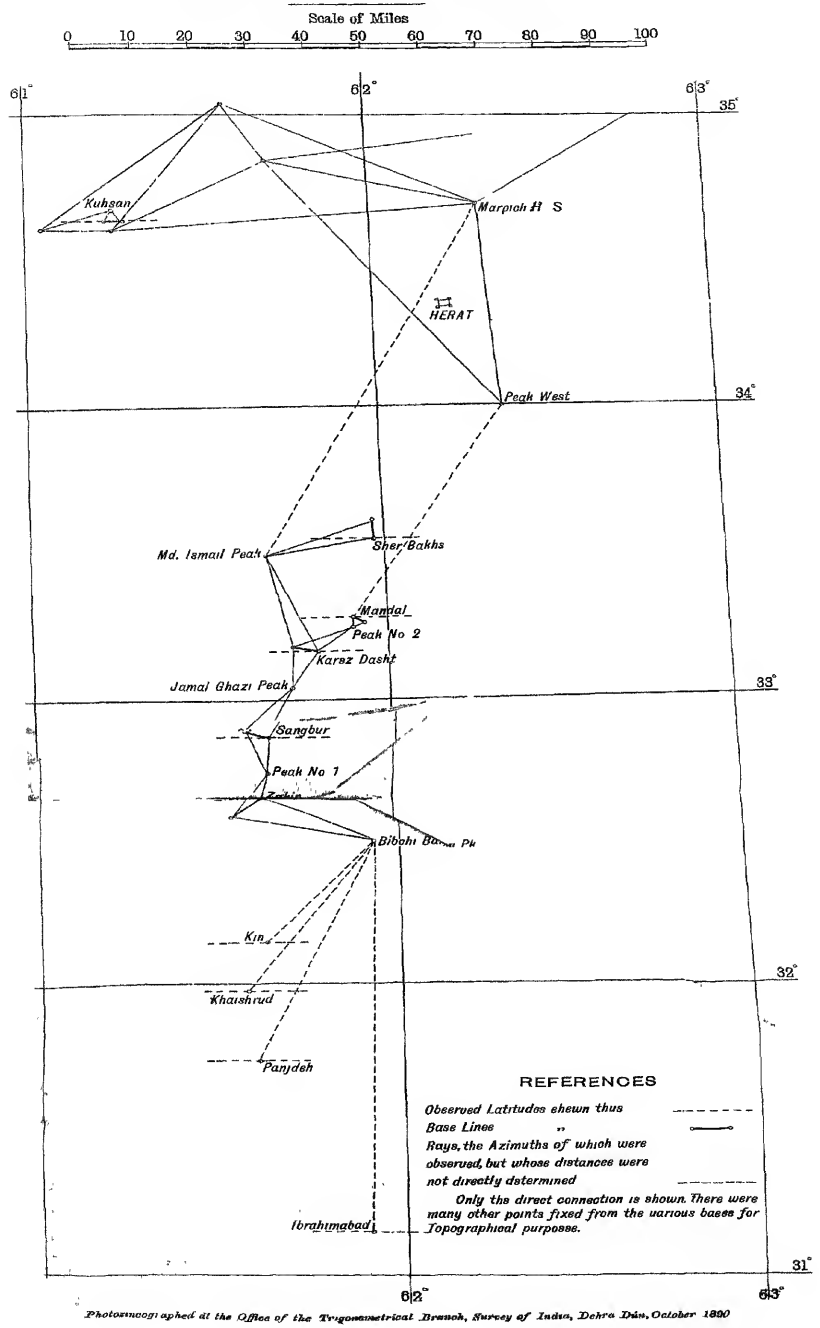
5. In inking up work great care should be taken to show what is reliable and what is not. If any site is placed at a guessed distance along a single ray, a portion of the ray should be inked in and a note of interrogation placed against the site. Everything that can be seen should be sketched in, as well as everything that can be gleaned from native information, and notes should invariably be made on the sheet itself to say how each portion was obtained. Such notes are invaluable to the compiler afterwards. When ground has been seen but not sketched, a general description of its character is better than nothing.

When reconnaissance work is being also done by other departments, such as the Quarter Master General's Department, effort should always be made to get the various parties to work as much as possible on the same points, so that the sketches may be combined.

When working with an army in the field, every endeavour should be made to keep a rough but complete compilation at Head-Quarters for the use of the General Commanding. New work should be added as it comes in and if doubtful points of compilation are then and there settled while enquiries can be made, this map will be invaluable afterwards when the fair mapping has to be done.

Every man plane-tabling or carrying on a connected sketch of any considerable area ought to keep a trace of all his inked-in work up to date. This trace should be left behind when he goes out to work, so that if he is attacked, and his sketch lost or destroyed, his previous work may not be lost too. The trace left behind will also be available for the compiler to use or for any officer to consult while the original is away. Traces of all work obtained up to date should frequently be sent to the base for use and safe custody.

Chart showing the Triangulation as executed on the march of the AFGHAN BOUNDARY COMMISSION between Ibrahimabad and Kuhsan for the purpose of fixing the LONGITUDE of Kuhsan




Photozincographed at the Office of the Trigonometrical Branch, Survey of India, Dehra Dún, October 1890